BACKGROUND STUDIES FOR THE DEVELOPMENT OF LONG TERM STRATEGY FOR THE CANADIAN SPACE PROGRAM

Philip A. Lapp Limited
CONSULTANTS TO INDUSTRY AND GOVERNMENTS

August 1985

HEAD OFFICE: SUITE 302, 14A HAZELTON AVENUE, TORONTO, ONTARIO, CANADA M5R 2E2
Phone (416) 920-1994

OTTAWA OFFICE: SUITE 904, 280 ALBERT STREET, OTTAWA, ONTARIO, CANADA K1P 5G8
Phone (613) 238-2452, Telex 053-3314

CONTENTS LIST

CONTENTS LIST (Cont'd)

CONTENTS LIST (Cont'd)

BACKGROUND STUDIES FOR THE DEVELOPMENT OF LONG TERM STRATEGY FOR THE CANADIAN SPACE PROGRAM

CHAPTER 1
INTRODUCTION AND BACKGROUND

1.1 Objective

The objective of this study is through reviewing the space plans of other nations up to the AD 2000 period and by assessing the impact upon the Canadian current Space Program and taking into account other factors, to describe the scenario within which a future Canadian Long Term Strategy might be formulated.

1.2 Scope of the Study

This report deals with Phase A of a two-phase study in this area, and has been conducted by a senior multi-disciplinary group of scientists and strategic analysts. A further Phase A "Comparative Economic Analysis of MSAT: RADARSAT; and SPACE STATION projects" is in process with Goss, Gilroy and Associates under contract to Philip A. Lapp Limited.

This report is organized into five chapters with four Appendices as follows:

<u>Chapter 1</u> - Introduction and Background

<u>Chapter 2</u> - Canadian Environment 1985

<u>Chapter 3</u> - A.D. 2000 World Space Scenario
This chapter projects the present world space scene forward 15 years in order to gain some appreciation of the factors that should influence the formulation of long-term Canadian space plans and policies.

This chapter is supported by three appendices as follows:

Appendix 1 - Communications
Appendix 2 - Remote Sensing
Appendix 3 - Trends - Space Science

Chapter 4 - Impact of the A.D. 2000 World Space Environment on the Canadian Space Program. This chapter assesses the impact of the A.D. 2000 environment on current Canadian plans and projects. In particular it attempts to identify threats and opportunities that should be considered in formulating a future plan.

Chapter 5 - The A.D. 2000 Marketplace, Market Factors and Strategies, and Program Formulation. This chapter draws Canadian Space Program major issues forward from Chapters 3 and 4 provides a summarization of world space technology issues; provides an outline model of the A.D. 2000 market and the obtainable segments of that market available to Canada, and concludes with brief comment on the organization and marketing effort in establishing a Canadian Space Program relevant to that milieu.

This Chapter is supported by Appendix 4 - The Impact and Use of the Regulatory Mechanism in the Development of the Regulatory Mechanism in the Development of National and International Space Strategies.

1.3 Background Comment on Strategic Issues

During the course of the analysis it has become clear that some nations are in a position of strong and broad-based leadership in the world space environment, others have equally strong established positions in selective special areas, and still others are moving gradually to join the "primary" nations in space science and applications.

This introduces a stronger element of competition into the world space program. The established pioneer nations - government having for the most part funded the R&D which has brought the space environment to its present state - are increasingly tending toward transferring technology and applications to the private sector. The maturation of space communications is the foremost example, the remote-sensing industry will be the next step. Maturation in space communications has covered a span of almost twenty years to this point. An equivalent level of maturity in Remote Sensing will require a similar timeframe.

But when the momentum for the commercial exploration of space innovation and technology becomes centered in industry the course of events becomes shaped by the marketplace and the demand-pull for end-products produced within the parameters of existing technology, at least cost, with minimum levels of up-front investment by the user/customer. Competitiveness relies on profitability for further innovation initiatives. Continued Governmnent conducted or funded R&D is essential to the process. This leads to cost-sharing between governments and industry on a continuous basis giving stability to the industry.

Major strategic issues in applications of space communication center on elimination of monopolistic advantages, standardization and regulation. Purchasing strategies of buyer nations, which themselves have aspirations of joining the world space industry complex, are directed to gaining technology transfer to establish their own national positions to become competitors of the primary sellers. Issues in the Remote Sensing field center (admittedly among other things) are the ability to achieve major advances in data-basing, and in data-interpretation to satisfy perceived customer and mission requirements which are now beginning to be defined in the marketplace. The demand-pull which is beginning to take shape in the Remote Sensing field accents instrumentation capability combined with data-base-interpretation requirements.

The perception of the world space environment comprising established pioneer nations, followed by nations (buyers at present) with plans to play a role as producers, and a third group which will always be buyers of end products poses a challenge for the established pioneers. Economic alliances among pioneer nations to defer and share the high cost of new initiatives to maintain their positions become increasingly attractive but difficult to arrange in the political context. Pioneer nations with broad-based space competence find it more and more difficult to maintain that broad based competence in the face of a highly competitive milieu. Buyers will have more options available to them. Most of the buyer demand will fall into the category of processed end-product information and services-communications, meteorology, resources management, surveillance, navigation. International marketing strategies of sellers become a key element of the world space environment over the next 15-20 years. For those space pioneer nations whose national programs consist of the selective stimulation of particular technologies, the challenge of the merging space industry nations may be somewhat more manageable. They may, in terms of selected concentration areas, be able to offset national costs by gaining export niches. The commercialization of world space program products from thirty years worth of R&D becomes one of the most crucial challenges for the pioneer space nations, the major responsibility for which will reside in industry with respect to the adoption of market driven applications.

CHAPTER 2
CANADIAN ENVIRONMENT 1985

2.1 Introduction

Canada is the only country whose space industry exports more, each year, than its government spends on space programs. While there could be several inferences drawn from that statistic, it seems clear that Canadian industry has been a very active and successful partner in the national program. At the same time, Canada has been fortunate that program managers in the public sector have been entrepreneurial themselves, and in large measure have found expression for that characteristic in like-minded individuals in the private sector. It has been a profitable relationship, satisfying national program needs on the one hand and promoting high quality jobs in industry on the other. The key ingredient has been people, and in particular a few farsighted individuals who set the pattern for the Canadian space program. The present stage of development is the result of their efforts, and will be the launching pad for activities over the next two decades.

The Canadian space program has developed in four program areas:

- communications
- remote sensing
- space science
- technology development

Ten federal departments participate in these programs, with three, DOC, EMR and NRCC having lead responsibilities. DOE, DND, DFO and MOT participate essentially as users; MOSST and DRIE provide coordination and industrial support, with EA responsible for international policy matters.

The elements of the program are at very different levels of maturity. The communications segment is mature, having reached the stage where there is an industry with sufficient capability to prime communications satellites and associated ground stations. Remote sensing technology is well developed, and Canadian industry competes successfully in international markets, particularly in data collection and analysis. The remote sensing component however, has not developed to the same extent as is the case for communications, and the program as a whole can therefore be considered somewhat short of maturity.

Canada's geographical location has presented some unique opportunities for scientists to contribute to the knowledge of the ionosphere and the phenomena associated therewith. The result has been a modest, but high quality, space science program, based in the past on a successful rocket and balloon program, augmented by participation in more elaborate international projects. The rocket and ballon activities have ceased, but international cooperative projects continue and the advent of the Space Shuttle, with Space Station on the horizon, presents opportunities to continue some of the investigations previously undertaken by ballon and rocket, and to initiate new studies making use of the longer periods available in microgravity.

In addition to the earth-bound facilities that support the above programs, the fourth element of the Canadian program involves the provision of specialized facilities on earth and platforms in space. One aspect of this segment of the program that has reached maturity is the Remote Manipulator System, developed as a Canadian contribution to the Shuttle. Based on this success, studies are underway to determine the extent and direction of Canada's contribution to the U.S. Space Station.

Pursuit of national programs has given Canadian industry the capability to compete internationally. But each country is intent on developing its own indigenous capability, with the result that large projects, such as the provision of a communications satellite, are undertaken jointly with partners. These operate under memoranda of understanding and industrial agreements, negotiated in part on a government-to-goverment basis, and in part on a company-to-company basis. This type of arrangement has proven advantageous to Canada, in as much as the Canadian content of our communications satellites has risen from about 13% on Anik A to about 65% on the most recent one, Brazilsat.

Our close association with the U.S.A. has resulted in a more extensive relationship with partners in that country than with some others, but there are joint agreements with partners in Europe and Asia. Thus Canada is firmly part of an international community developing space applications. In fact, Canada was the third nation in space, and has been one of the leaders in space technology.

This position has been achieved although our expenditures are modest by international standards, aobut the same as India and somewhat less than Italy. In 1985/86 federal expenditures will be about $194M, divided approximately:

- communications 20%
- remote sensing 38%
- space science 12%
- technology development 30%

Included in these estimates are funds supporting three major projects, at different stages of development, each involving the construction of large operational systems. These will be outlined below. In addition, about 30% of the funds support the base activities in the program areas, and about 50% go toward approved projects within these areas. The Canadian program is well positioned technologically to move to the next stage of development, and the issue will be how to most effectively use this base to maintain our national position.

2.2 Programs

2.2.1 Communications

The current program in communications has developed from 1962 when Canada became the third nation to launch a space satellite. The motivation at that time, as it is now, was to provide a communications network that would link together our large and sparsely populated country. Space provides the medium now, much as the railroad did in the last century.

While the driving force behind the program has been national need, the industry-government partnership that developed has put Canadian industry in a position to act as prime contractor for the supply of national and foreign communications satellites. During this period when the program was maturing, technology was continuously advanced, largely through the supportive efforts of the federal government, by a series of technology projects, ranging from applications through systems and subsystems to materials. Each of these has been designed to improve performance and competitiveness, and has resulted in the development of key Canadian technologies that have found a niche in the international market place.

The goal of the program as a whole has been to develop operational systems. This has been done successfully, and the domestic satellite system is operated by Telesat Canada, a mixed public-private sector corporation established as the "carriers' carrier" within Canada.

Teleglobe Canada is the Canadian Crown Corporation with responsibility for providing international interfaces with Canada's national common carriers and other users of international telecommunication facilities. These interfaces fall into three main groups, satellite telecommunications facilities, terrestrial and land-line facilities, and underwater long-line telecommunications facilities.

Satellite facilities are leased from Intelsat and Inmarsat, with Teleglobe Canada operating ground stations linking services to national common carriers, broadcasters and other international facilites users. The terrestrial interface links the U.S. - Canada land-lines with the common carriers, while the underwater services provide switching stations, and copper, coaxial and fibre optic cables.

The communications program also provides services to SARSAT, the search and rescue satellite, and NAVSTAR, the space navigation system, both operated by DND.

The present approved program includes the DOC operations "A" base, and funding for three projects - mobile satellite support, COMSAT applications and SARSAT and NAVSTAR. Five projects underway in the early 80's have terminated and SARSAT, NAVSTAR funding is decreasing. A major program is awaiting decision - mobile satellite (MSAT).

MSAT is the result of an arrangement entered into by DOC and NASA on November 28, 1983, to cooperate in the definition of a space program leading to the development of a communications satellite to meet mobile communications needs in both countries. Potential users include telephone companies, radio carriers, resource industries, trucking, governments and emergency and law enforcement agencies.

By the end of 1985, the project definition phase will be completed with a Canadian investment of about $25M. Implementation is estimated to cost an additional 175M.

Telesat Canada, joint venturing with a U.S. domestic satellite operator, will operate the system.

In 1985 Canada has an operating domestic satellite communications system, a strong technology base in government and industry, and a well-developed industrial infrastructure poised to meet national and international needs in this subject area. The program is mature, in the sense that it is commercialized, but orbit crowding and the needs of developing countries for their share of slots, will drive technology ever forward, and Canada will have to be part of this process if it is to maintain its present capability and competitive position.

2.2.2 Remote Sensing

The Canadian remote sensing program started about a decade later than the communications program, and arose as a result of the development of the U.S. earth resource satellite program. The foundation of the program has been access to data acquired by foreign owned and controlled satellites, and this has been achieved through a number of international agreements and memoranda of understanding.

The aim of the program is to make available to Canadian users, information for a variety of purposes, including, resource management, environmental management and management of Canada's coastal responsibilities. Because the program deals with information, it has focussed on three key elements:

- data collection technology
- data processing technology
- applications technology

Although there is at present no complete Canadian operational remote sensing program including satellites, nevertheless there is a comprehensive capability in the above three technologies, resulting in an industrial sector that competes successfully internationally. Comparing the size of the Canadian program to those of other countries, this is considered to be quite an achievement.

Three departments participate in the program, with EMR, through the Canada Centre for Remote Sensing, in the lead position. The program, consists of certain "A" base operations augmented by eleven specific projects. A number of the latter are on-going, and relate to the reception of data from Landsat and in the near future, SPOT, along with technology transfer activities, environmental monitoring and image correction systems. DOE has several projects dealing with the reception and dissemination of data from weather satellites.

Two large projects involve participation with ESA, and are associated with ERS-1. Canada will provide a SAR processor, space telemetry and data handling for the satellite, and will establish a Canadian ground read-out facility. These activities will ensure that Canadian industry remains in the forefront of technologies in which we now have demonstrated competence.

Finally, there is a major pre-operational system in the design stage - RADARSAT. This satellite will provide information essential for the safe and efficient navigation of ships in waters off Canada's north and east coasts. It will also provide information on land resources.

The spacecraft for RADARSAT will be provided by the UK, with NASA participating in the overall project. There is also a possible German and French involvement in sub-systems. As the program moves forward, potential commercial partners such as Telesat, will participate to ensure that commercial benefits are realized.

In addition to federal involvement, many provincial organizations have established centres to develop applications for remote sensing data that are specific to their province. Several of these centres have been very active, developing not only specific methods for data anaysis, but also technology associated with these methods. A significant difference between the communications and remote sensing programs in this regard, flows from the division of constitutional responsibilities.

In summary, the 1985 Canadian remote sensing environment can be characterized by:

- a strong technological base in sensor development, data acquisition (including reception) and image analysis
- well developed and highly competitive industry
- international involvement which is critical to all phases of the program
- provincial centres interfacing with users

Remote sensing has not as yet been commercialized to the extent of the communications system, and is still in the process of developing a large and committed user community. Canadian technology is in the forefront, and is able to sel competitively into foreign markets. The program has not reached a mature stage, but the base is strong and firm.

2.2.3 Space Science

The Canadian space science program over the years has focussed on studies of the ionosphere and on the physical processes that occur in the upper atmosphere. The program has been a training ground for scientists and engineers (about one half of the participants are in universities), and has significantly promoted the development of Canadian industry; one leading company began as a result of this program and a second received its first hardware contract for a space science instrument.

In earlier years, much of the activity involved the use of balloons and rockets, which are well suited to experiments requiring short residence times in microgravity. There has also been a sustaining program whereby Canadian scientists, through a Canadian principal investigator, can participate in international programs on a "project of opportunity" basis. This mix of available vehicles has been well matched to the training of graduate students, who require a few years' turn around time. Approximately 39 graduate degrees were awarded in 1984, with a further 14 scheduled for 1985/1986.

The rocket and balloon program terminated in 1984, so attention has shifted to use of the Shuttle and more extensive international cooperation (rockets and balloons are still used in other countries). The longer duration flights available on the Shuttle, and later with Space Station, have made it possible to enlarge the program area to the investigation of materials processing in microgravity. The availability of satellites as platforms for astronomy investigations, usually through cooperative international programs, has also opened up this field for Canadian astronomers.

While the use of microgravity and committed participation in space astronomy are still not fully developed, there is nevertheless an on-going program to investigate upper atmosphere phenomena and space plasma physics. Canada is participating in the Swedish Viking satellite program, and will be investigating auroral acceleration processes. Charged particle measurements at Jupiter, over the solar poles and in interplanetary space will be carried out in a cooperative program with NASA and ESA. Experiments on neutral winds and plasma waves are in the development stages in cooperation with NASA. Two materials processing experiments have started and two ionosphere/upper atmosphere investigations have been approved.

The projects referred to above are extensive undertakings requiring the development of sophisticated instrumentation. Other more modest projects involve the testing of materials in microgravity, and participation with U.S. investigators in studies of human adaptation to microgravity.

The Canadian space science program has been successful, not only in training of scientists but also in forging links between the academic, industrial and public sector communities. With the termination of the rocket and balloon program, and the incomplete development of a replacement involving the Shuttle and Space Station, the program appears to be in transition. Many if not all ionosphere/upper atmosphere investigations can be undertaken with the latter platforms, but we must have access and a turn around time that accommodates the graduate training schedule, if we are to maintain a cadre of professionals in space science.

2.2.4 Technology Development

Five federal departments participate in the space technology development program - DOC, DND, NRCC, DRIE and MOSST. About one half of the resources are consumed within the "A" base, and the remainder are distributed among seven projects. Four deal with Anik D premiums, RMS follow-on, Canadian Astronaut program and in the ESA OLYMPUS satellite communications program. Of the others, the largest at present is the development of the L-SAT bus, in cooperation with the UK, as the platform for RADARSAT, with further applications projected in the future.

The operation of the David Florida Laboratory, Canada's major satellite integration and testing facility, falls within this program. This is the facility that performs the ground testing of Canadian satellites and is available to other nations as required.

During the last few years, preparatory studies have been underway to identify possible areas of participation in the U.S. Space Station program. These have culminated in a decision to commence, in 1985, a definition and design phase leading to identification of the nature and extent of Canadian participation.

The present plan calls for the development during the next two years of four work packages.

- space construction and servicing facility
- solar arrays
- remote sensing facility
- user programs

This program segment builds on technology developed in Canadian industry through the RMS and communications programs, as well as the instrument development capability generated through the remote sensing program.

Canada's user community, at least those who are commercially oriented, are not well advanced on the learning curve with regard to experience in microgravity. Some encouragement and incentives will be required to give impetus to this aspect of the program, which in the final analysis, is where the ultimate benefits will be obtained. As with the space science program, access to microgravity is an issue, and the proposal to develop a small Canadian platform offers one solution.

The technology development program has peaked - at least in terms of number of projects - but will expand signficantly with participation in Space Station. As with other elements of the space program, Canada is in a strong position to build on existing strengths and move into a new technological era.

2.2.5 Summary

An examination of Canadian capability reveals a very strong base in a range of technologies, built up over the years and peaking at the present time. Projects in support of specific niche technologies are decreasing in number. At the same time, very large programs are in advanced planning/development stages. Support for any one of the latter could well consume all available resources, assuming there is no increase, without sustaining the broad base that exists today. We therefore appear to be at a threshold where we will have to examine our programs carefully to be sure we do not needlessly narrow our current well-developed base.

2.3 Decision Process

2.3.1 Objectives of the Canadian Space Program

The federal government has adopted the following broad objectives for the Canadian Space Program:

- ensure that the potential of space technology for practical applications to meet Candian needs is fully developed
- encourage the development of competitive space industries
- ensure that Canada maintains a position of excellence in the world-wide scientific exploration of space

These goals are in fact derivatives of much broader national goals that both flow from and are responsible for the Canadian constitution. Not surprisingly, the consitution is silent on jurisdiction with respect to space - as it is for research. However, since residual powers devolve to the federal government (perhaps fortunate for Canada and the provinces in this instance!), it seems clear that responsibility for "managing" space lies with the federal level.

It may be worth noting that the space goals could equally well apply to, say, the oceans, with one very significantly different circumstance. We can define boundaries - 200 mile limit - , and control access in terrestrial policy areas. It is somewhat more difficult in space. This leads to the principle that space is international, and although there will be particular national interests regarding information that can be gathered therefrom, the approach will generally be on an international basis. We should conclude then, that in space matters we cannot "go it alone".

2.3.2 Government-Industry Relations

National goals are important, but equally so is the process by which they are achieved. In Canada we have been fortunate, in as much as the public sector responsible for identifying the national needs to be served has, from the start, recognized that the engine of growth is the private sector.

As a result of the symbiotic relationship between government and industry, we are now in a position where

- Canada is the only country where space industries sell more than the government spends on its space program
- space industries have been growing at more than 50% per year
- sales in 1983 were about $300M
- 70% of sales are exported
- the industry is 90% Canadian owned
- sales contain about 75% Canadian value-added
- the industry is distributed regionally
- employment is greater than 3200
- several companies are world leaders.

If all other industrial sectors in Canada were able to perform as well, a major pre-occupation of the federal government - the national debt - would be dissipated in short order. In fact, the issue might not even have arisen! We can only conclude that as a nation we have done something right. The challenge is to keep it going.

Much has been made of the "fragmentation" of the Canadian Space Program. But without prejudice to the future, it was probably that "fragmentation" that was responsible for getting us where we are now. Each of the four present program areas have been developed as a result of one individual within that area who had the foresight to <u>demand</u> attention, and the tenacity to wring resources out of a somewhat reluctant system in order to promote his cause.

At the same time, there have been a number of individuals in the private sector who have also had the foresight to seize opportunities, and working with their counterparts in government, have jointly developed the strong industrial infrastructure that exists today. Although there may be other conclusions that could be drawn from a reflection on our recent history in the space program, it is inescapable that individuals, not structures, have been key elements in the success. Individuals, however, come and go. National circumstances change, and while the lessons of the past should never be forgotten, they do not always hold the key to a magic future.

Today in Canada we face the following set of circumstances:

- we have a strong, broadly-based, competent and competitive space industry, poised to grasp a bright future
- there are extensive and expensive major projects queuing for approval, any one of which could consume a significant part of the current space budget
- limits on financial and human resources might preclude the provision of support necessary to be at the forefront of all areas of space activities.

Resolution of issues embodied in the above will have a very profound impact on both the public and private sector participants in the space program. While leadership must come from the public sector, execution lies with industry. It is not surprising therefore, that industry has strong views on how decisions affecting their own future are taken.

The industry position is embodied in three perceived requirements:

- the existence of a strong and clearly directed national space program
- a long-term commitment from the federal government
- an effective management structure within government.

Explicit in the industry position is the need for decisions on both substance and process. There is also an expressed view that these decisions cannot be postponed unnecessarily if the industrial competitiveness is to be maintained.

For its part, the federal government had initiated a number of diverse projects and in doing so has developed a healthy industrial offspring that requires continuing and probably increasing sustenance if it is to flourish. We thus see an uneasy balance of needs and resources that must be stabilized if the national goals are to continue to be achieved and benefits realized.

2.3.3 Strategies and Constraints

As noted previously, the application components of the space program - communications, remote sensing and now Space Station - have appeared on the scene sequentially

- about a decade apart. It is therefore difficult to determine whether the present strategy for administering the overall program has come about through serendipity, or whether it is part of a grand plan.

Certainly, over the years the issue of a space agency has been raised, only to subside, welling up again when a particular constituency believes such a step is crucial to overcoming a perceived problem. From the government side, it has long been a policy that the R & D performed by departments are in suport of their missions, and thus must be dealt with in that framework. That philosophy is consistent with the present structure.

There is also the issue of how the government decides. Departmental programs are presented by the responsible minister, and colleagues must be persuaded that the advocate's proposal is the most important among many others. It can be likened to one individual against the rest, although this is too simplistic a view. However, it does appear that with the present arrangement, the total space program is agreed to at the officials level, and when it reaches cabinet there are in principle four ministers who are advocates. If number is the main criterion for funding decisions, this beats a single minister hands down! Once again, it is not clear if this circumstance is the result of chance or a well thought out strategy. Whichever one obtains, it appears to have worked up to the present, which is not to say that the process cannot be improved upon.

Any strategy is proscribed by constraints. In the case of space, the latter can be described as:

- the traditional approach that R & D supports missions
- the history of the overall program development
- the need for each department to feel in control of the elements that determine the effectiveness of program delivery
- very severe competition for rather scarce resources

For all these reasons, the space program is one where a Ministry of State can play an important role in what is in fact an administrative - if not management - matrix. We have national goals for space, but no national management structure. It is illuminating to contemplate the recorded perception of the Australian team that looked extensively at how national space programs are managed. Canada received full marks for its ability to develop a competitive industry. The administrative structure deemed most suitable for Australia is tnat of France.

So in 1985 we have the following:

- a successful space program
- a national goals but no national leader
- strong departments where space has an important role in program delivery
- an industry that perceives there is insufficient leadership, and perhaps even sagging commitment

The evidence points to success in the past, either by design or happenstance, but with the importance of the decisions that lie ahead, and the consequences for all involved sectors, the plea for at least a more visible management structure should not pass unheeded.

2.3.4 Socio-Economic Factors

There is no doubt that the impact of the space communications program on national unity objectives has been very large. Anyone who tried to communicate from the Arctic to southern Canada 20 years ago, and has repeated that experience in the last decade, can attest to that perception. And communication goes beyond simply conversation; all Canada's cultural broadcasting is available anywhere - for the price of receiving equipment. The is one measure of a mature program.

The remote sensing program which includes certain aspects of weather forecasting, has also had an impact, but of a somewhat different nature. Sensor technology, combined with data and image analysis development, have provided a tool for resource management that is finding ever increasing application. We can now revise the national reconnaissance level maps directly from remotely sensed data; management of B.C. forests is largely based upon remote sensing; data can be collected on wheat production world-wide, important to Canada's wheat growers; sea state and pollution can be monitored more completely and effectively. Applications in this field may be be as eye-catching as in communications, particulary where TV is concerned, but are nevertheless impacting very significantly on our quality of life.

Space science is the basis for much of our present technology program. Initial investigation of phenomena in the ionosphere were key to the successful development of satellite communications. Instrumentation required for upper atmosphere research has pushed the state-of-the-art and helped to launch industry in time for the present space activity. People have been trained, and Canada has an enviable reputation for the quality of its space research.

While the economic returns from research are often realized only in the future, social returns in terms of international cooperation and access to developments elsewhere are immediate and enormous. Space science forms one essential ingredient in contributing to the social and economic fabric of the country.

The largest economic impacts of the space program have been realized in the number of high quality jobs generated in industry, and the regional distribution of these jobs. Involvement in space technology has been synergistic at the last, and deterministic perhaps, in establishing "regions of technology" such as Saskatoon, Vancouver and the Ottawa valley.

Furthermore, space is a growth industry, and therefore we can look with some optimism to that sector to continue its contributions. At the same time, and acknowledging that risks will be, and can be, borne by industry, these risks can only be properly evaluated in the presence of an understood national purpose.

2.3.5 International Cooperation

For many reasons, not the least of which may be defensive in terms of technology, space is generally an international theatre. Probably only two countries have, at this time, a complete and comprehensive space capability - USA and USSR. Many others have specialty areas where they can compete favourably, and it is probably correct to assume that all nations with space interests, buyers or sellers, will aim to develop or enrich indigenous technological capabilities.

In such circumstances few countries are able to build programs that will provide other users with turn-key operations. There will be "start-up" purchases or particular platforms, but experience shows that nations are reluctant to be totally captive to a technology that resides in another country - particulary a single country.

Furthermore, space endeavours are expensive and risky, and not many countries are in a position to fully support the development of even a single satellite, let alone a complete system. As a result, there are several suppliers for each sub-system, and a number of system integrators, so the buyer has an opportunity to select from a fairly broad menu.

There is also the national cultural imperative, concerned mainly with communications and data collection. Both of these are sensitive issues and have been the subjects of many memoranda of understanding over the years. And protection of technology has also become important.

In this complex international milieu, Canada, along with other countries, has sought security and refuge in bilateral/multilateral agreements at both governmental and industrial levels. In most cases, these agreements have been for specific purposes with fixed duration, or at least with renewable clauses. An exception is ESA, which itself exists as a result of a set of international agreements involving mainly a number of European countries (Canada is an associate member). It is worth noting that about 40% of the funds flowing to ESA-promoted projects goes to ESA general support.

Although our main relationships remain with the USA, we do have extensive understandings with ESA, a number of European countries and Japan. China and Brazil have been customers with Nigeria a hopeful prospect. Provision of systems has involved joint agreements with suppliers in other countries, while Canadian sub-systems and components have often been negotiated into the systems of other countries in return for access (to a platform for example).

Countries operating remote sensing satellites have the ability to collect/disseminate information over most of the regions of the world. It cannot be taken for granted that read-out will be free, or even available. There is also an issue regarding the collection of information on one country by the satellite of another. A corollary is the definition of "boundaries" when collection of data is over oceans. Although these considerations could lead to excessive complexity, and be difficult to handle equitably, in practice memoranda of understanding have provided satisfactory vehicles for resolution of potential problems.

In total, it appears that the system world-wide is operating satisfactorily, but it will continue to do so only if governments have the will and the wit to skillfully negotiate their country's interests. And this is likely to be most effectively accomplished if the negotiators are well informed both politically and technically.

2.3.6 Purchasing Policies

As early as practical in the Canadian Space Program, and the concurrent development of industrial capability, the concept of a prime contractor was established. This has been held to have been the key toward

- maximizing Canadian content on Canadian spacecraft
- obtaining industry access to, and participation in international markets
- increasing overall technological capability

The success of the prime contractor concept depends critically on its acceptance by the main purchaser - the federal government. While there is generally some reluctance for governments to become tied to a single supplier, Canada's requirements alone cannot support competition between primes, so we are therefore left with little choice other than to accept a partnership with a chosen instrument.

The arguments in favour of a prime contractor are compelling. The prime controls design, and that is critical to supply, i.e. the health and development of sub-contractors. The availability of a supply infrastructure assists a Canadian prime in dealing with foreign partners, and helps to maximize Canadian content in international joint programs.

The success of the concept in relation to communication satellites has been demonstrated by the growth in Canadian content from 13% on Anik A to 65% on Brazilsat. Work placed with the present sub-contractor industry has grown from zero on Anik A to over 20% on Brazilsat, and may reach 30% on future similar programs.

In addition to establishing a prime contractor for communication satellites, the federal government, through its departments, has been a strong advocate of contracting space related requirements to industry. This philosophy has been largely responsible for developing the industrial infrastructure that is now present, and has enabled Canadian industry to compete successfuly internationally.

As has been remarked previously, we appear to have done some things right, and one of these is a sensible government purchasing policy.

CHAPTER 3

THE AD 2000 WORLD SPACE ENVIRONMENT

3.1 Introduction

The purpose of this chapter is to project the present world space scene forward 15 years in order to gain some appreciation of the factors that should influence the formulation of long-term Canadian space plans and policies, now and over the next few years. Accordingly, the focus will be on those elements that are related to Canadian interests, and no attempt will be made to be exhaustive, or to achieve completeness.

Space activities important to Canada include:

a) Space transportation and launchers

b) Communications

c) Navigation and Positioning

d) Remote Sensing and Meteorology

e) Space Science

f) In-Orbit Infrastructure - Space Station

g) Materials Processing

h) Military Applications

i) Ground Support Facilities

There is a plethora of reports and data covering these subjects and the plans of nations and agencies. They generally span in some detail the period up to 1990, after which the specifics become more general and plans become increasingly vague. Nevertheless, trends can be discerned and an attempt has been made to synthesize an AD 2000 scenario in each activity area covered.

The principal agencies and nations with current national space programs include:

- USA - NASA, NOAA, DOD, private sector
- USSR
- European Space Agency - ESA
- Canada
- Japan
- France
- Germany
- Italy
- Sweden
- United Kingdom
- China
- India
- Brazil
- Indonesia
- Other Third World Countries

Each of these nations has interests in one or more of the activities listed above, but there will be no attempt to deal with all of them in the paragraphs to follow, except insofar as such interests have a significant bearing on the AD 2000 world scenario.

In order to place the world space scene in perspective, Table 3.1 is an estimate of world space expenditures in 1983.

Table 3.1

Comparative Space Expenditures* - 1983, for Selected Countries & Agencies

Country	Organization	Expenditure $ Millions	% of Total
USA	NASA (6,122) Dept. of Defence (8,502) Other Orgs. (216)	14,840	42.6
USSR	Defence more than 75%	18,000	51.6
Japan	NASDA - 85% of total	470	1.35
Canada		133	.35
India		90	.25
Europe	ESA (705) National Programs (635)	1,340	3.85
		$34,873	100%

---

* From ESA Bulletin 37

While there are no such formal estimates available for AD 2000, the Centre for Space Policy, Inc. has made estimates for the potential value of business opportunities for space*. It estimates a range from $16.8 Billion to $51.3 Billion per year by the year 2000, broken down as follows:

Table 3.2

Potential Value of Business Opportunities for Space - AD 2000

by Centre for Space Policy, Inc. 1985

Activity	Range - $ Billions		
Materials Processing	2.0	-	17.9
Communications	8.8	-	15.3
Ground-Based Support	4.1	-	10.4
In-Orbit Infrastructure (orbital services)	0.6	-	2.8
Remote Sensing	0.5	-	2.5
Space Transportation	0.2	-	2.4
Total	16.8		51.3

The lower end of the range in Table 3.2 corresponds to the non-USSR figures for 1983 (from Table 3.1, whereas the high end is a factor of three larger. However, the important point to note is where the business will be focussed: 85-90% will be in materials processing, communications and ground-based support. The largest component of materials processing is in pharmaceuticals; communications including fixed and mobile services, and direct broadcast; ground based support (mainly earth stations), and also insurance and payload processing.

The above global figures are included only to give an indication of size and emphasis. It is speculative at best to forecast

* Aviation Week, July 8, 1985, p. 91

total expenditures 15 years out; however, ESA has published a long-range space plan* which suggests a 1.5 Billion AU (European Accounting Unit - approximately equivalent to one US dollar) average annual expenditure over the 11-year period 1985-95, up by nearly a factor of 2 from 1983. European national programs generally approximate ESA contributions for the large countries. Moreover, European nations have singled out space as a major growth area of investment. Thus, by 1990, the total European component of space expenditures could well be a factor of 2-3 above those of 1983. A doubling of US expenditures from 1983 to 2000 would amount to an annual increment of 4% (the approximate rate of inflation). Using these figures would place non-USSR AD 2000 world space expenditures in the order of $35 Billion. Such an estimate could be in error by as much as 50%, which sets a range from $17.5 Billion at the low end (approximately to-day's expenditures) to $52.5 Billion at the high end. Interestingly these figures correspond closely to those generated by the Centre for Space Policy (Table 3.2).

While the total magnitude of world space expenditures gives some feel for size and level of effort, it is how these expenditures are distributed that is important to the development of a Canadian space plan. The following paragraphs deal with each relevant space activity in turn. The information is drawn from a wide range of sources to which the reader is referred for more details.

3.2 Space Transportation and Expendable Launch Vehicles

3.2.1 National Programs

Only the major space powers have developed operational launch

---

* ESA Council, Outline of a Long-Term European Space Plan, ESA/C (84) 46 Rev. 1, Paris, 21 November 1984.

vehicles - US, USSR and France - but other nations have moved into the field: Japan, China and India. For the purposes of this study, the USSR will not be considered.

The US has set the world pace in space transportation and launchers, having now proven the operational effectiveness of the shuttle space transportation system (STS). In its 1985 Long-Range Program Plan, NASA has adopted two major goals for its Space Flight program:

- make STS an efficient, effective business enterprise that will arrest the loss of space transportation customers in the near term and develop new customer markets in the long term.

- to establish a more permanent presence in space.

NASA's Space Flight program has established objectives into the 1990's which:

- capitalize on the STS as a space test bed for R and D activities.

- devise innovative uses for the STS

- provide routine, flexible, economical access to all orbits for both cargo and manned payloads.

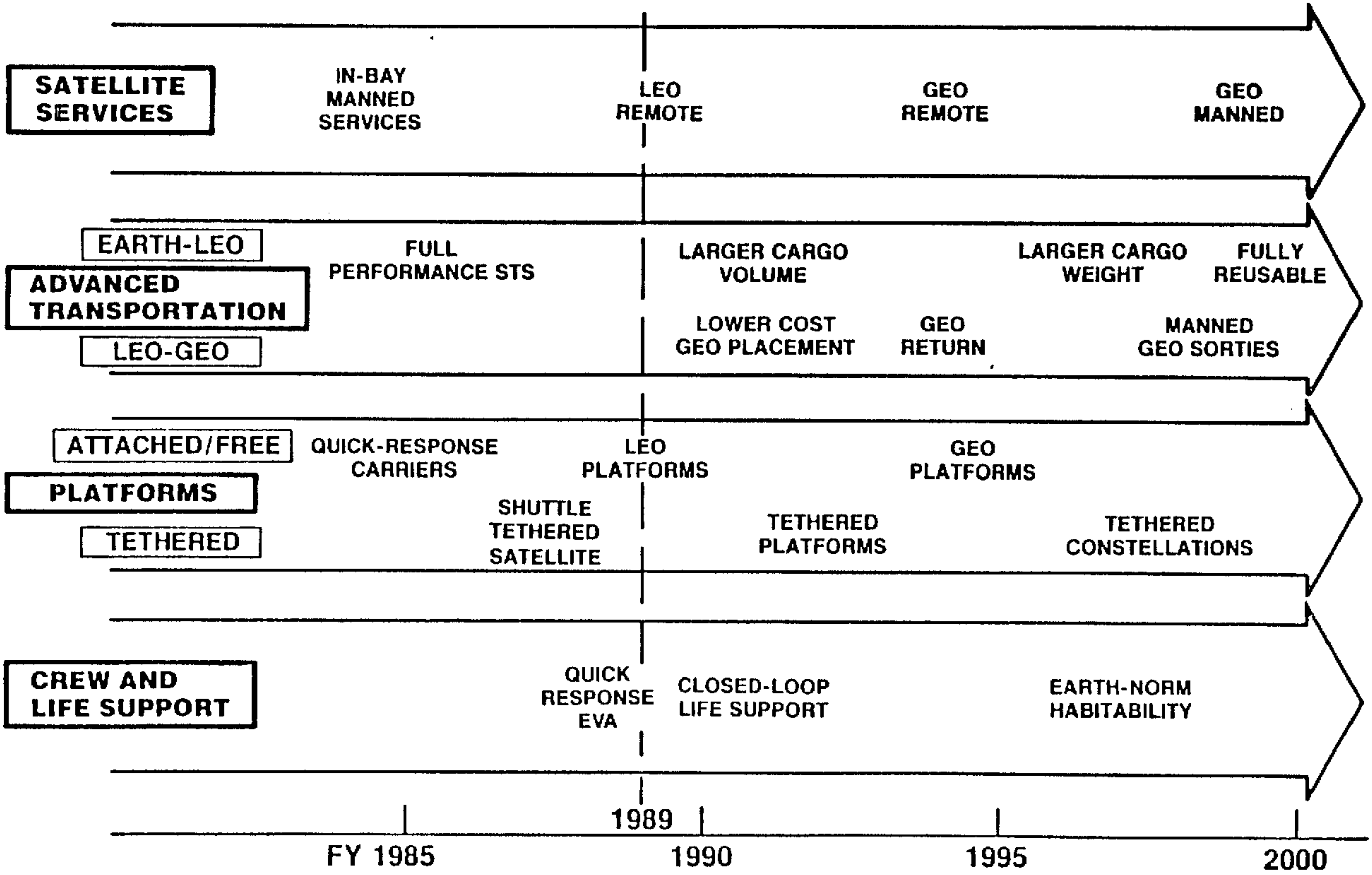
- increase the time in space and economical operation of payloads by establishing permanent space facilities to support science, R and D, commercial and operations activities, both manned and unmanned, in low and geostationary earth orbits.

- institute routine checkout, refuelling, repair and upgrading of spacecraft in orbit through manned and remotely-controlled servicing.

The STS constitutes almost the whole of NASA's Space Flight baseline program through to AD 2000. By that year, four shuttle vehicles will be in full operation, and possibly a fifth. The Capability Evolution Plan is shown in Figure 3.1. By AD 2000, it will be possible to place man in geosynchronous orbit (GEO), operate fully reusable high-capacity cargo placements

FIGURE 3.1*

CAPABILITY EVOLUTION PLAN



LEO = LOW EARTH ORBIT GEO = GEOSYNCHRONOUS ORBIT EVA = EXTRAVEHICULAR ACTIVITY in GEO, conduct manned GEO sorties from low earth orbit (LEO), operate tethered satellite constellations from space station or the shuttle, and operate closed-loop support for crew and passengers for all such missions. Table 3.3 lists the STS capabilities that will be possible in AD 2000.

NASA's expendable launch vehicles (ELV) currently include the Scout, Delta, Atlas and Atlas-Centaur systems. They will be used over the next few years to accommodate launch assurance in case of slips in shuttle schedule, and be phased out as STS capability increases. However, the private sector is expected to move into the ELV field and offer launches at competitive prices to NASA and other nations. The result of this initiative is difficult to forecast, but it can be expected that at least some will survive until AD 2000 to create an extremely competitive international and U.S. domestic environment for ELV launches at that time.

In addition to STS, NASA expects, by the year 2000, to develop two other transportation systems: the Orbital Manoeuvring Vehicle (OMV) and the Orbital Transfer Vehicle (OTV). The OMV will be a reusable extension to the STS for conducting operations with spacecraft and payloads in orbits beyond the orbiter's practical operational limits. It will be a free-flying, remotely-piloted vehicle for use with the STS, and later with Space Station, to perform satellite servicing. The OTV will be the principal means of transferring payloads from LEO to GEO and return. Initially it will be unmanned, but later versions will permit the transfer of man to GEO as shown against "Advanced Transportation" in Figure 3.1.

The principal competition to the US ELVs and STS is the French/ESA Ariane launch vehicle. Current plans call for product improvement programs for Ariane 3 and 4, but the main thrust in the latter

TABLE 3.3 STS CAPABILITIES*

Shuttle

Delivery of Tended and Untended Satellites and Other Payloads to Low Earth Orbit
Repair and Retrieval of Spacecraft
Delivery of Propulsive Stages and Satellites to Low Earth Orbit for transfer to High-Energy Orbits
Delivery of 29,500 kg (65,000 lbs) of Payload to 250-km (150-nmi) circular orbit
return of 11,340 kg (25,000 lbs) of Payload from Space

Spacelab

Payload Capability: 4,800 to 8,000 kg (10,600 to 19,400 lbs)
Pressurized Volume: 8 to 22 m^3 (280 to 775 ft^3)
Average Electrical Power: 3 to 5 KW
Payload Specialists: 1 to 4
Nominal Mission Duration: 7 days

Inertial Upper Stage (2-Stage)

Delivery of up to 2,270 kg (5,000 lbs) to Geosynchronous Orbit

Payload Assist Modules (PAMs)

Delivery of 1,270 kg (2,800 lbs) to Geosynchronous Transfer Orbit (PAM-D)
Delivery of 1,995 kg (4,400 lbs) to Geosynchronous Transfer Orbit (PAM-A)

Centaur-G Prime

Delivery of 5,895 kg (13,000 lbs) to Geosynchronous Orbit (Centaur-G: 4,535 kg (10,000 lbs))
Delivery of 2,360 kg (5,200 lbs) to Outer Planets (C^3 = 85 km^2/sec^2)

* From: 1985 NASA Long Range Plan

1990s will be the Ariane 5 which will rely on the large cryogenic, 80-tonne thrust, HM-60 engine now beginning its development cycle. During the nineties the competition is expected to become much tougher than today. Launch capacity will no longer be in short supply and, in addition to NASA's STS, new ELVs will be operational (such as the Japanes H-II and probably a stretched US ELV, capable of placing 2000 kg and 4500 kg respectively in GEO, as compared with 2500 kg for Ariane 4).

Accordingly, Ariane 5 will exhibit significant improvements in cost-effectiveness to GEO and in reliability (to reduce insurance costs which now amount to 20-30% of launch costs). It will also provide for an increased shroud diameter to match the STS figure of 4.5 metres (compared with 3.65m for Ariane 4). Ariane 5 will be cost effective for LEO missions and be capable of subsequent man-rating for orbiting a spaceplane (e.g. approximately 15 tonnes in LEO for the HERMES* spacecraft now under study by France's space agency, CNES). Ariane 5 should become operational in the late 1990s.

By the 1990s, Japan's H series cryogenic launch vehicles will be operational, with H-I capable of launching 550 kg into GEO, and H-II capable of 2-tonnes into GEO. China will attempt to underprice Ariane, STS and US ELVs to garner a share of the international launch service market. The CZ-2 for moderate LEO payloads and the CZ-3 for small 1300 kg GEO payloads will make up the principal marketing emphasis. Finally, India's ISRO (Indian Space Research Organization) is moving toward operational capability - the Advanced Satellite Launcher Vehicle (ASLV) being able to deliver 150 kg. to LEO, and the Polar Satellite Launcher Vehicle (PSLV) to launch, in the early 1990s,

---

* HERMES is a small manned recoverable spacecraft which, for some types of missions, could become a competitor to STS.

1 tonne into a sun-synchronous polar orbit from the Indian launch site on the island of Shriharikota, 100 km from Madras.

3.2.2 Summary

The above portrayal of the AD 2000 launch capability scenario suggests a plurality of launchers in a very competitive marketplace. Add to this an aggressive private sector entry into the launcher field, mainly from the US, which may survive to the year 2000, and the competition intensifies further. Thus, the availability of launch capacity should not be an issue for Canada in the year 2000. The cost per kg. per unit of diameter in LEO and GEO should be substantially less (in constant dollars) than at present. Moreover, the possible advent of Hermes as a competitor to STS could permit Canada to be less dependent on US space transportation services than is currently the case - although this conclusion is totally dependent on ESA funding of Hermes, which has yet to be confirmed.

3.3 Communications

3.3.1 General Environment and Competitive Technology

Satellite communications are dealt with in detail in Appendix 1, to which the reader is referred for organizations, structures, plans and programs at the international, regional and national levels. The Appendix also covers new technologies and applications, and the impact of the regulatory environment. The following paragraphs deal with trends and the particular circumstances that will have a direct impact on the AD 2000 environment for satellite communications.

Space communications is the one application of space technology that has already achieved a measure of maturity. International, regional and national systems are now in place and functioning as a world-wide network for telephony and TV. By the turn of the century, it can be expected that many such systems will be digitized, and that a world-wide Integrated Services Digital Network (ISDN) will be in place.* Such a network will consist of satellite links and optical fibre blended in a complementary fashion, and will include such telecommunication services as:

- voice
- television
- computer-to-computer data transfer
- teleconferencing (audio and video)
- facsimile (slow and fast)
- packet switched data
- slow-scan TV
- electronic mail

While such a digital panacea may represent the brave new world of telecommunications in the next century, the dynamics of current events make it difficult to foresee exactly how the satellite role will emerge. Specifically, it is the rapid installation of optical fibre at present that is clouding the picture. Over the next 15 years, it is reasonable to expect that every major centre of population in North America will be interconnected by fibre of sufficient bandwidth to eliminate the need for alternative services, except for emergency. Europe appears to be moving more slowly for a variety of social, political and economic reasons, but the same general trend is occurring

---

* Satellite Technology, July 1985, p. 30

there as well. Other regions doubtlessly will follow, although at an even slower pace.

Completion of the TAT-8 transatlantic fibre optic cable in 1988, the first of four, followed by other submarine fibre cables across the Pacific and Indian Oceans, will make significant inroads into the market for intercontinental traffic.

The major explosion in fibre unquestionably will be at the wide and local area network levels. However, there is no doubt that fibre will impact the longer distance markets now served by satellite. As high efficiency, single-mode fibres improve in performance, the frequency of repeaters and other costly electronics will decrease, so that both capital and operating costs will drop. As a result, operators will be driven off satellites and onto fibre, especially where heavy relay traffic occurs such as in trunking applications and city-to-city links.

3.3.2 Fixed Satellite Service

The satellite market most heavily affected by fibre is the so-called fixed satellite service (FSS), which provides a common carrier link for point-to-point and point-to-multipoint transmission. Traffic consists mainly of voice, video and data. The basic markets are the telephone companies (Telcos), the TV broadcasters and those offering business data and voice services. The largest users of FSS are the Telcos (in Canada they own 49% of Telesat Canada), which also own and are installing additional terrestrial plant, mainly fibre. Within 15 years, most Telco trunking and heavy inter-city traffic currently served by FSS will have reverted to terrestrial plant. Broadcast trunking will undoubtedly follow the same path, although Pay-TV and Cable headend switched interconnections will represent an expanding FSS market.

The development of private networks to serve special corporate needs is beginning to emerge in the US, particularly for point to-multipoint, where there is a headquarters-branch plant structure. Such services cover voice, video and data, and can be competitive with the Telcos particularly where the branch offices are distant and located away from heavy traffic locations. Future network services by satellite will employ switching facilities in the satellite itself and the use of spot beams, thereby moving away from the conventional relay role now being taken up by fibre. The Centre for Space Policy envisages major growth in this private sector FSS usage by the turn of the century.

FSS currently operates in C-Band (6/4 GHz) and K_u-Band (14/12 GHZ), but in future higher frequencies in the EHF spectrum will find their way into service. C-Band service, which requires large antennas (in the order of 10 m. diameter), is most likely to feel the major impact of fibre. K_u-Band, with its smaller antennas (1 m. diameter) and thus less costly earth stations, is likely to be the candidate for private networks and expanding Telco thin-route use. Except for the military and Japan, higher frequency applications (K_a-Band and EHF) are mainly experimental at present, but will be increasingly important as spectrum and orbital positions become more crowded.*

Major growth in FSS is anticipated in third world countries which will help use up some of the C-Band slack created by the Telcos over the next decade or two. These nations are anxious to take up their share of geostationary orbit before it is lost to the more developed countries.

Thus while certain fixed services are losing ground because of Telco preference for terrestrial fibre plant, markets are expanding for private networks and in the third world. The net effect is continued growth of FSS, but at a somewhat slower

---

* By the end of 1985, some 110 communication satellites will be in geosynchronous orbit; by AD 2000, the number will increase to about 400.

pace as fibre's impact is felt.

In a study conducted by Eurospace for ESA in 1984*, it was projected that 221 communication satellites would be launched world-wide between 1986 and 1993 at a pace which begins at 23 to be launched in 1986 and ends up with a projected 35 to be launched in 1993. If the same pattern continues to the end of the century, the figure in AD 2000 could approach 50 satellites per year. These figures include all classes of communication satellite including FSS, direct broadcast and mobile services. The FSS proportion will decrease as the other classes begin their penetration of the total market.

3.3.3 Direct Broadcast Satellites

Direct Broadcast Satellite service (DBS) has had a difficult entry into the marketplace. Aside from the high, up-front capital costs of satellites, DBS firms have had great difficulty in securing affordable programming. Nevertheless DBS services are expected to grow through the 1990s. DBS will operate at K_u-Band, and probably higher frequency bands as well, where the cost of earth stations will be more affordable to the public. Economics will drive the DBS market, and it has been estimated by the Centre for Space Policy that, at the high end, DBS and FSS will share equally in the AD 2000 market at the $6.7 Billion level.

3.3.4 Mobile Satellite Service

Land mobile communications services in North America are concentrated in the urban areas. Service to the balance of the region is, at best, inadequate, and in large sections of Canada, totally

---

* Eurospace - Study of the Workload of the European Space Industry, Summary Report, App. 2, ESA Contract 5240/82/F/F2(SC)

non-existent. Where land mobile service exists, it is characterized by over-crowding, spotty coverage and incompatibilities between equipment due to frequency and other differences. While cellular service offers an answer to most of these problems, its coverage will always be limited by economic considerations, and vast areas will be left unserviced by cellular, even by AD 2000.

Mobile satellite communications services (MSS)* have been studied at length and in depth by the U.S. and Canada. Designed for mobile, thin-route applications, MSS can be interlinked with present cellular systems to provide a total service, interconnected into the telephone system, for <u>any</u> location within line-of-sight to the satellite at synchronous orbit. Thus it is ideal for a country like Canada with its vast territories now unserviced by other forms of reliable communications. However, ideal as it may be, the start-up economics appear to be marginal until the service gains a broad acceptance in the marketplace. By its very nature, such a market will not be characterized by high-volume, concentrated usage.

The major uses of mobile satellite services by AD 2000 are likely to be focussed on the transportation, exploration and rural telephone markets. The transportation market will be dominated by the intercity trucking industry where drivers beyond cellular coverage can maintain close contact with dispatchers. Other mobile operators will include railways, airline, automotive, marine and field operations away from population centres. Exploration applications include the oil and gas industry in the arctic and remote areas, as well as remote mining and construction sites. Rural telephone, while not

---

* While Inmarsat serves marine vessels and thus mobile markets, it operates in the 1.5 GHz and 6/4 GHz bands; thus we have considered it as a fixed service. It is described in detail in Appendix 1.

mobile, can be economically served by MSS and thus represents a separate use of the service.

In North America, NASA and DOC are cooperating in MSS, and a jointly-shared, 800 MHz Mobilesat (MSAT) system is being planned for operation in the early 1990s. The US FCC has received 12 applications from the US private sector. Services proposed include voice and data for mobile, aeronautical and marine; paging; facsimile; positioning/interactive data; surveillance and telemetry. By the turn of the century, most if not all of such services could be in operation, and second generation MSats will be in service. By then, the service should be profitable to the operators.

MSS is also being planned in Europe and Japan. Japan now operates an experimental service, and Europe (ESA) has identified a Mobile Satellite Service mission, particularly for land mobile applications at L-Band and/or UHF.

3.3.5 Satellite Communications Earth Stations

The above satellite services - FSS, DBS and MSS - embody a signficant market in earth stations including special stations for telemetry, tracking and control (TT&C). The earth station market has always been very active and competitive, and it can be safely assumed that as electronic and materials technology advance, the cost of such stations will continue to fall. The extension of the FSS market into the third world, the emergence of private networks and DBS, and the introduction of MSat service in the 1990s should assure a strong demand out to AD 2000. If that demand is elastic, then earth station sales should show exceptional strength by the end of the century.

As to the structure of the earth station market, it is likely that the TV Receive Only (TVRO) consumer market has nearly peaked and is unlikely to show significant growth as increasing numbers of channels turn to scrambling to prevent non-subscriber reception. To some extent this could be offset by dropping prices - current prices could be halved by AD 2000. TT&C station numbers will expand as third world countries procure their own satellites, but FSS business services, DBS and MSS services all will require TT&C and expensive uplink stations as well.

DBS earth stations represent a very large future market; the number of potential urban, rural and remote area subscribers in Canada has been estimated at 1.9 to 2.6 million* by the mid-1990s, assuming access to both Canadian and US programming. US figures are difficult to estimate because of the differing distribution of subscribers with access to alternative services such as cable. Perhaps a factor of 5 is appropriate, leading to a figure in the order of 10-15 million US subscribers by the mid-1990s. By the year AD 2000, the market for new subscribers will likely by approaching saturation, but by then the replacement market should be brisk. Markets in these magnitudes will obviously attract acute competition.

The mobile satellite earth station market should be growing rapidly by the late 1990s, assuming the service is introduced as planned, circa 1990. By AD 2000, second generation satellites will be in operation, and mobile satellite services likely will be in place in Europe and Japan. Third world markets should be opening up as well. However, while the prices of MSS earth stations are likely to be of the same order as DBS stations (in the range of $1000 - $2000), the total numbers

---

* Dept. of Communications, Direct-to-Home Satellite Broadcasting for Canada, June, 1983; Figures 17 and 18.

are likely to be an order of magnitude less; but they still represent a substantial market, attracting strong competition.

3.3.6 Data Relay Services

NASA operates a space and ground network of tracking and data systems to support inflight missions. It consists of three basic elements: a space network, ground networks, and communication and data systems. The space network in the mid 1980s is evolving from a network of ground tracking stations located around the world into a network of two Tracking and Data Relay Satellite Systems (TDRSS) satellites in geostationary orbit, with an in-orbit spare, a single ground terminal at White Sands, New Mexico, and a network control centre at Goddard Space Flight Centre (GSFC) to control the system and manage the network. By the mid-1980s, NASA will close nine of its fifteen ground stations around the world. Three of the remaining stations form the deep-space network (Australia, California and Spain), but most important, the remote sensing Landsat series and meteorological GOES series will both be transferred over to TDRSS via the White Sands/GSFC network. NASA could, if it wished, cut off all foreign Landsat ground stations thereby necessitating the purchase of imagery from the U.S.

By the 1990s, new relay capabilities will be needed. NASA plans more links, greater (Gigabit) capacity, a relay-to-relay link, and direct relay-to-ground links. By AD 2000, optical and millimetre wave telecommunications will be in place which will be able to cope with the enormous data bit rates expected by then.

ESA is planning its own Data Relay Satellite System, DRS-1, a two satellite system planned for the mid-1990s. It will be needed for the Columbus-associated free flying platforms and earth observation programs (see Section 3.7). The two satellites will use microwave links to ground, but could be linked together by an optical telemetry beam. Direct dissemination to multiple mission centres is being planned.

Satellite-aided search and rescue (Cospas/Sarsat) is a cooperative multinational effort in which Canada, France, USSR and the USA are developing and demonstrating a global satellite system for detecting and locating the position of signals transmitted automatically from aircraft, marine vessels and individuals in distress. The program has been most successful - it is claimed that 350 lives have been saved since the first system was put into place in 1982. The Sarsat package is carried on board the NOAA polar orbiting satellites. It would appear most likely that future versions of SARSAT will be in service in AD 2000.

3.3.7 Summary

The above paragraphs are intended only to paint a broad AD 2000 world scenario and indicate trends in space communications. For more detailed market forecasts, the reader is referred to professionally-performed market studies such as those produced by the Center for Space Policy, Inc. In general, the space communications environment at the turn of the century will be:

- intensely competitive
- widely international, with major third world involvement
- substantial in dollar volume (the high scenarios for space and earth segments for the US alone amount to $24 Billion in 2000, according to the Centre for Space Policy).

Opportunities for total spacecraft, systems, units and components supply will assure an active industrial environment. However, because of the major government and private sector capital investments involved, it is unlikely that major changes will take place in the prime contractor structure now established world-wide. They include:

USA:	Hughes Aircraft (HAC) RCA Ford Aerospace TRW
UK:	British Aerospace/MATRA (France)
France:	Aerospatiale
Germany:	MBB/Erno

Each of the prime contractors has its own bus and payload designs which, one way or another, will find their way into the various competitions over the coming decade. In future, and by the end of the century, the major trend will be toward higher and higher payload end-of-life power. Current satellites such as the Hughes HS 376, Ford Insat, RCA 3000 series are in the order of one kilowatt, whereas future buses expected in the 1990s will be in the 3-4 kilowatts range (e.g. RCA 4000 and Hughes HS 393 series).

The highly competitive environment of the late 1990s will almost certainly involve many of the above prime contractors interacting with their first tier suppliers in an environment dominated by political and economic forces. While technology will continue to play a significant role, price and country alignments will determine who will survive to enter the 21st century as a strong, profitable entity.

Not to be overlooked is the burgeoning earth station market of the late 1990s. Again, price will be the driver of this market, and the number of suppliers undoubtedly will be exceedingly large. Since the market will be dominated by small earth terminals ranging from a few hundred dollars to perhaps $2000, the size and financial strength of suppliers need not be large. Thus the earth station supply structure will be highly volatile and dominated by the then low-cost producers - probably still the Pacific rim countries.

3.4 Navigation and Positioning

Satellite navigation and positioning has been made globally available by the US military for over 20 years for use essentially by Navy vessels and surveyors. However, recent interest in such a service has been stimulated by the opportunity for commercial use of the USAF Navstar Global Positioning System (GPS), new initiatives from the US private sector (Geostar) and opportunities made possible by the introduction of a mobile communications satellite service.

Recent filings at the FCC have been made by prospective operators of civil satellites for locating the positions of special mobile transceivers*. Applications of such a service include the positioning of land vehicles and aircraft, safety of corporate aviation, calibration of mapping and aerial photography, locating fire and intrusion alarms, collection of environmental data, cargo monitoring and railroad car locating - most of which can utilize MSat services as the communications and billing media for a commercial service. Should such services become available in the US, they also could be made available in Canada, although surprisingly there does not yet appear to be any initiative in this direction.

Two effects are used in global satellite navigation: the Doppler effect as a satellite passes overhead, and the use of the time a signal takes to travel from a number of satellites to measure ranges to them. The Doppler effect is used in the early systems such as the US Navy's Transit satellite, the Cospas/Sarsat search and rescue system (working like Transit in reverse,

---

* Aviation Week; June 3, 1985, p. 371

i.e. the fixed frequency beacon on the distressed vehicle, the receiver and relay on the satellite), and for one mode of ESA's Navsat proposal. Ranging or pseudo-ranging techniques are used in GPS, ESA's Navsat, the MSat-related services and Geostar.

The Transit and Cospas/Sarsat systems have the disadvantage that position fixing is not continuous, but occurs only once every satellite pass which could create intervals from over one to four hours between fixes. Accuracies range from 1 -3 miles.

ESA'S Navsat Doppler mode provides continuous coverage because a number of satellites are seen during any one measuring frame.

Ranging techniques used by GPS involve a constellation of 18 satellites in nominally circular 20,169 km orbits inclined at 55 degrees, with three satellites equally spaced in each of six orbital planes. As a military system, the satellites are designed to be jam resistant. GPS has two codes - the C/A code for essentially civilian use, and the P code, encrypted for military users only. While the P code is the most accurate, the C/A code is degraded in accuracy to 100 metres, having been reduced from 500 metres, and then to 200 metres, and which could be degraded as the US military sees fit.

The proposed US Geostar is based on a single, central supercomputer at the system control location on the ground, and a constellation of three satellites in geosynchronous orbit. User equipment is a simple digital transceiver whose only function is to exchange messages with the satellite which, in turn, relays data to the central computer. The projected retail price for user equipment in 1987 is $450. Geostar Corporation claim three-dimensional accuracies of 1 to 7 metres. With such accuracies, the system could be used in aviation for ILS, ATC and Collison

Avoidance purposes, as well as for terrain avoidance.

While Geostar is an active system inasmuch as the user must transmit a message up to the satellite, ESA's Navsat system is entirely passive. However, like GPS it requires a constellation of 18-24 satellites, but since the system does not need to be autonomous as does GPS, control can reside in the ground segment, so that the satellites are merely repeaters. Since the system is passive, users cannot be billed on a "per fix" basis, as in Geostar.

The systems based on MSat will use either the Geostar concept or the C/A code from GPS as the basis for a positioning service. Complex calculations are transfered to management centres which simplifies user equipment, and the MSat service is used to transmit position data to the user, and for billing purposes.

By AD 2000, one or more civilian satellite navigation and positioning services are likely to be operational, in addition to GPS. Any US service will certainly be commercial with a billing system similar to conventional telephone, cellular and mobile services. If ESA is able to persuade enough nations to cover the initial capital costs of a Navsat-type system with regional control centres, then it is possible that a totally passive service might be available by the end of the century where the user pays only for the cost of a receiver, but not additional usage charges.

3.5 Remote Sensing and Meteorology

3.5.1 Introduction

Remote sensing and meteorology are intended to embody all civilian space activities related to earth observation. The first US meteorological satellite was launched on April 1, 1960, and such satellites have now become part of the global weather forecasting system, working in close conjunction with earth-based data gathering systems. In the US, the provision of meteorological data is considered to be a "public good", and thus future space meteorology will continue to be a governmental activity. The National Environmental Satellite, Data, and Information Service (NESDIS) manages US civil operational earth-observing satellite systems, as well as global data bases for meteorology, oceanography, solid-earth geophysics, and solar-terrestrial sciences. An agency of the National Oceanic and Atmospheric Administration (NOAA), NESDIS develops and provides environmental data and information products to other NOAA agencies and international weather services. NESDIS operates two polar-orbiting weather satellites which monitor global weather and surface conditions, and two geostationary weather satellites which observe eastern and western sectors of North America. NESDIS also operates two earth resources satellites, Landsats 4 and 5, in polar orbit.

Earth observation became an ESA program with the advent of the Meteosat program in the early 1970s. Meteosat-1 launched in 1977, and a second satellite launched in 1981 provide Europe's contribution to the World Weather Watch of WMO, delivering images of the European/African sector of the globe every 30 minutes. Continuity is assured at least to the mid-1990s by the planned launch by ESA of three further Meteosats, funded by Euometsat.

Japan's contribution to the World Weather Watch (WWW) is the geostationary meteorological satellite GMS covering the western Pacific. India's Insat, a communications and TV broadcast satellite, carries a meteorological package and provides images for WWW, and a geostationary USSR metsat GOMS is being planned for a 1986 launch.

Figure 3.2 shows the operational earth observation satellites now in service. Appendix 2 is an overview of policy statements of major space nations on earth observation from space with respect to the next decade. It also summarizes trends, key new technologies and the competitive environment out to the turn of the century.

While the provision of meteorological data, the related data acquisition programs and R&D will remain government operated and dominated, recent steps taken by the US government will shift land remote sensing into the private sector. The provision of raw data, which entails the space segment and ground station data acquisition activities, has been the most active and visible so far. However, in future, the value added data processing industry, wherein raw data is turned into useful information products, will become the largest component in terms of revenues and number of participants.

The following paragraphs focus on future directions in remote sensing and meteorology under the headings land satellites, environmental satellites and value-added services.

3.5.2 Land Satellites

In 1972, the first of five NASA Landsats was launched. For more than a decade, the Landsat series has provided observations that have been used to manage renewable resources, such as crops and forests, to assist in the discovery of non-renewable resources such as oil, minerals and coal, and to monitor the environment.

At present, two Landsat satellites are in orbit (Landsats 4 and 5), which operate through a control and data processing facility at NASA's Goddard Space Flight Centre. While the Landsat system was originally developed by NASA, NOAA assumed

Operational Earth Observation Satellites

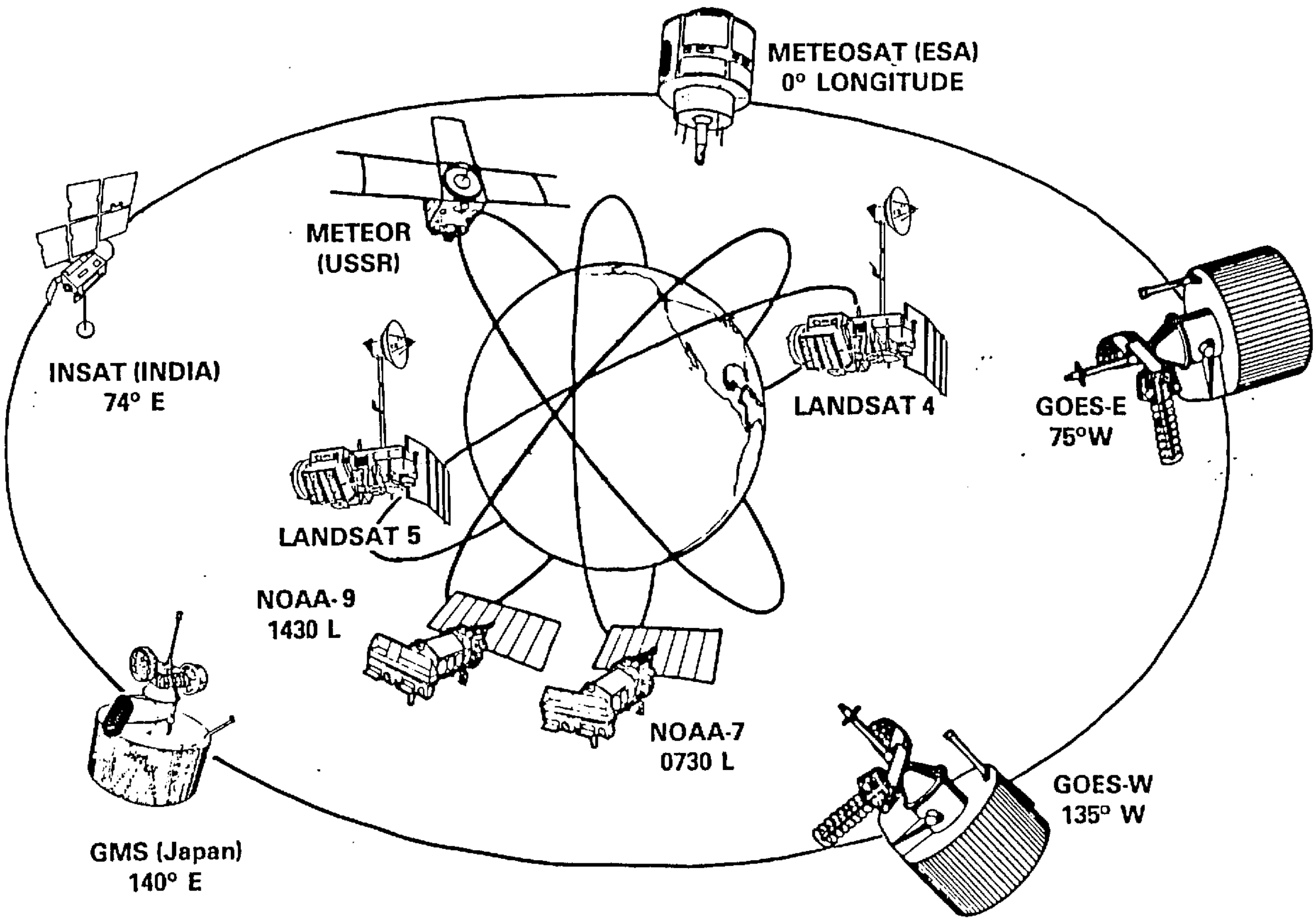


FIGURE 3.2

operational responsibility on January 31, 1983. During its first seven months in orbit, Landsat 4 developed a series of technical problems, and so Landsat 5 was launched on March 1, 1984. NOAA is responsible for controlling the spacecraft, scheduling the use of its sensors, and processing and distributing the data through the Department of Interior's Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota.

Landsat provides nearly global coverage. The orbit is near polar and sun-synchronous, and the satellite is maintained in fixed orbital paths. There are 233 such paths spaced equally around the earth, and each path is covered once in 16 days.

All Landsats have carried a multispectral scanner (MSS) with 80-metre spatial resolution in four spectral bands. MSS can provide 136 images (scenes) per day for US use, and 337 scenes to international ground stations. Landsats 4 and 5 also carry a more advanced sensor, the thematic mapper (TM), with 30-metre resolution in six reflective bands and one emissive (thermal) band. TM can acquire 100 scenes per day for domestic users, and 160 scenes per day for international users. The advantages of Landsat data derive from its global coverage, the digital format of its imagery, the spectral bands that are covered and the wide-area views provided by the satellite's altitude. The principal disadvantages are the incidence of cloud cover which obscures the imagery, resolution, the 16-day gap between successive images of the same point and the lack of stereo capability.

A major issue with the Landsat program is continuity. The US government made the decision to commercialize Landsat, and put the program up for commercial competition. The program was finally awarded to EOSat, a joint RCA-Hughes venture; however, there have been long delays before the transfer was finally approved. EOSat will take over Landsat 5 as soon as the contract is signed, and will build and fly Landsat 6 by December 1988. The problem is that Landsat 5 has a design lifetime of only 3 years, and thus can be expected to remain in service only until March, 1987. Therefore, a gap of over twenty months can be expected.

Alternative data sources include the NOAA metsats and the soon to be launched French Spot satellite (late 1985). The Advanced Very High Resolution Radiometer (AVHRR) carried by the Advanced Tiros N series (now NOAA-7 and NOAA-9) provides imagery and quantitative radiance data at 1 km and 4 km resolution in 5 spectral bands - much lower resolution than MSS, but useful for some agricultural purposes.

Major Landsat-series competition will come from the French Spot 1 satellite due to be launched by Ariane in October, 1985. It will produce imagery at a resolution of 10 metres in 4 spectral bands. While its coverage interval will be 26 days, it can point its sensor either side of the flight path and thus provide stereo images by observing the same terrain on two successive passes. Spot data will be marketed by Spot Image, a company with a majority state holding. Later versions of Spot to be launched through the 1990s will have added sensors such as an ocean colour imager and vegetation index mapper.

Spot Image intends to follow the "Open Skies" policy adopted by the US in response to complaints by nations overflown by Landsat that the US has no right to acquire imagery over another state's sovereign territory. Under this policy, raw imagery is available to all buyers at one price; thus US firms do not gain an unfair advantage in evaluating other nations' imagery for economic gain.

The US has been collecting Landsat data through a network of nine ground stations - 2 in the US, and seven foreign stations: Canada, India, Thailand, Sweden, Brazil, Australia and Japan. This network will not be used after TDRSS becomes available (except for Indian and Thailand where there is a gap). All data will be received via TDRSS at a single ground station in White Sands, N.M. and then transmitted by a US domestic satellite to NOAA/GSFC in Maryland. NOAA has signed, or is about to sign, thirteen Landsat MOUs with:

Argentina	Indonesia
Australia	Japan
Brazil	Pakistan
Canada	Saudia Arabia
China	South Africa
ESA (3 Earthnet stations)	
India)	Thailand

It is likely that EOSat and the Landsat program will lose ground generally to Spot Image due to the anticipated gap in the program. However, the significant physical plant already in place to receive Landsat MSS and TM data should add sufficient momentum to carry the program into the 1990s and beyond. By then, however, still further earth observation satellites will be in operation including ESA's ERS-1, Canada's Radarsat and Japan's JERS-1, all of which will offer some competition to the existing land satellites because they carry synthetic aperture radar (SAR) sensors capable of penetrating cloud and darkness, thereby overcoming a major weakness of the Landsat/Spot imagers that operate in the visible/IR region of the spectrum. These microwave satellites will be covered in the following section.

During the mid-1990s, as part of NASA's space station program, a man-tended platform in near-polar, sun-synchronous orbit is being planned. Such a platform could be a major step in operational earth observations, and an impressive array of sensors is being proposed. For land applications, one proposal is to include a High Resolution Imaging Spectrometer (HIRIS) having a 10 metre spatial resolution, with a spectral band 10 nanometers wide, selectable on-orbit, over the range from

0.4 to 2.5 microns. A development version of this instrument is to be tested on the shuttle, called the Shuttle Imaging Spectrometer Experiment (SISEX).

3.5.3 Environmental Satellites

For purposes of this study, environmental satellites support services that provide forecasts of weather, atmosphere, oceans or ice conditions. There are essentially two types of environmental satellites: geostationary and polar orbiting. Two US Geostationary Operational Environmental Satellites (GOES-East and GOES-West) observe eastern and western North America from their vantage point over the equator, but also cover areas which extend well into the southern hemisphere. These satellites provide day-night images of the earth, using a Visible-Infrared Spin-Scan Radiometer (VISSR) Atmospheric Sounder (VAS), monitor hurricanes and severe storms, relay meteorological data from surface collection points to a processing centre, and transmit processed graphic and imaged weather data (WEFAX) to field stations. They also monitor the magnetic field and energy particle flux in the vicinity of the satellite, and observe x-ray emissions from the sun. Later versions, known as GOES Next, will have a more extensive sensor complement including a search and rescue transponder, and the program will undoubtedly extend through the 1990s into the next century. As described earlier and shown in Figure 3.2, ESA's Meteosat, India's Insat and Japan's GMS also provide weather data from geosynchronous orbit.

Polar orbiting environmental satellites include the current NOAA Advanced Tiros-N series for monitoring atmospheric and other parameters including temperature and humidity in the earth's atmosphere, surface temperature, cloud cover, water-ice boundaries, and proton and election flux near the earth. They carry the Search and Rescue (Sarsat) transponder described in Section 3.3.6. They also receive, process and retransmit data from balloons, buoys and remote automatic stations distributed around the globe (the ARGOS Data Collection and Platform Location System, provided by France). Later versions, to be launched in 1990-92, known as NOAA-K, L and M will carry passive microwave sensors, possibly an ocean colour instrument and other refinements. Advanced versions, known as NOAA-Next, will carry the series through the 1990s.

Satellite-borne civilian microwave sensors were initially aimed at ocean measurements. The leading satellite in what has become a long line of microwave remote sensing systems was Seasat A, launched in 1978. It operated for only 100 days. Seasat carried a synthetic aperture radar (SAR), a wind scatterometer called the Seasat-A Satellite Scatterometer (SASS), a Scanning Multichannel Microwave Radiometer (SMMR), a precision altimeter and a Visible and Infrared Radiometer (VIRR). These instruments proved their value during the short life of this satellite.

The SAR provided imagery of the ocean with a spatial resolution of 25 metres. This imagery was so spectacular when it was first viewed that it caused a major shift in the planning of future environmental satellites. The Seasat SAR gave rise to other SARs incorporated into the following satellites:

- ESA's ERS-1
- Japan's JERS-1
- US Navy's N-ROSS
- Canada's Radarsat
- NASA's Shuttle Imaging Radar (SIR)

SAR applications include oceanography, ice reconnaissance, renewable resource assessments and the detection of non-renewable resources, all of which are important to Canada. Experience on Seasat, and the SIR radars on the Shuttle (which revealed the ability to penetrate dry surface layers to expose geological features below) suggest that radars optimized for ocean phenomena are not necessarily optimal for ice or land applications, and thus the applications need to be carefully focussed. ESA's ERS-1 is planned to be launched in mid-1989, Canada's Radarsat approximately a year later.

It is worth noting that the Canadian firm MacDonald Dettwiler and Associates (MDA) conceived and developed the electronic image processor for Seasat. MDA is now responsible for the development of the processor and ground receiving station for ESA's ERS-1 satellite and Canada's Radarsat.

The success of the SASS scatterometer wind sensor gave rise to the incorporation of similar sensors in ERS-1, N-ROSS and Radarsat. The SMMR, also flown and still operating on NASA's Nimbus 7, has led to the incorporation of microwave radiometer sensors on two military meteorological satellites - the Defence Meteorological Satellite Program (DMSP), to be launched in 1986, and the Navy Remote Ocean Sensing System (N-ROSS), to be launched in 1989. Known as the Special Sensor Microwave Imager (SSM/I), it provides all-weather measurements of ocean surface wind speed, ice edge location and the amount of precipitation. The SSM/I could be of particular value to Canada because of the need for wind values off both coasts to aid in weather forecasting. The precision altimeter on Seasat has led to an improved altimeter with a 2 cm. precision, to be flown on NASA's TOPEX mission to determine ocean circulation more precisely.

Nimbus 7 carries, in addition to the SMMR, the Coastal Zone Colour Scanner (CZCS) - a visible and infrared multispectral radiometer in bands that provide important biological productivity data. A successor to CZCS, the Ocean Colour Imager (OCI), will be flown in the 1990s, possibly on later versions of ERS-1.

Between late 1985 and mid-1989 more than one billion dollars of satellite sensors designed for oceanic measurements will be launched by the USA and other countries. According to NOAA/NESDIS, operational wind, wave and sea ice data will be increased from its present level of 2000 to 4000 reports per day to 2,000,000 plus in the 1989-90 time frame. This meets the marine community's global requirements for these data sets, as well as data on sea surface temperature, currents, circulation and ice sheets.*

Throughout the 1990s and by the turn of the century, environmental satellite data and derived products will find their way into the world's operational weather and environmental forecasting services. Today such information is only beginning to be accepted in an operational sense, but the time of ingestion is long when it comes to the introduction of new technology into a large service (such as AES) that operates massive, on-line systems 24 hours a day. Moreover, most environmental data is shared internationally, and exchanged at no cost from one country's service to the others. Facilitated by the WMO, all nations are linked through an infrastructure that needs to absorb the new technology - time will be required.

By AD 2000, the major space powers - US, ESA, Japan and the USSR - should be orbiting a broad array of environmental satellites, some of which will be experimental, but most of which will be feeding on-line data into various countries' environmental forecasting services. On-board data processing, using artificial intelligence techniques, likely will be generating derived information products for direct application by forecasters. However, the most important observation is the plurality of

* NOAA Satellite Programs Briefing, March, 1985

data sources that should be coming available. The likelihood of duplication because of the focussed interests of civilian and military agencies, and of each nation's sovereignty and special concerns or circumstances, suggests a buyer's market for satellite data by the turn of the century.

3.5.4 Value-Added Services

Value-added services generally mean those activities that convert raw, remotely-sensed data into derived information products needed by an end user or client. They include the application of any calibration or corrections to the raw signal needed to yield appropriately processed data products, the performance of data or image interpretation and formatting, and the derivation of final information products that are meaningful to the client such as a resource manager or environmental monitoring agency. Value-added services include all or any part of such activities.

Generally speaking, the acquisition of satellite meteorological and oceanographic data, including the cost of satellites, ground stations and data processing facilities has been underwritten entirely by governments. The user community for such data has mainly been governments; however, some private sector weather services have been established to service special interest groups, such as the offshore drilling industry, the yachting community, or the provision of routing services for shipping companies. Such private sector environmental forecasting businesses use far more than just satellite data; in fact such an industry existed long before satellite data became available. It uses all the data it can get. However, as satellites become more sophisticated and effective, they will undoubtedly find their way more into operational use than in the past.

Most governments, certainly Canada and the USA, have ruled that meteorological and oceanographic data should be made available as a public good, so that the government charges the private sector only the extra costs incurred in providing it the data. However, as satellite data usage increases, and when the value-added industry shows signs of growth and prosperity, governments will be tempted to recover more of their costs from this user community.

Such forces have already been at work on the Landsat program. The US government was of the view that Landsat ultimately would benefit the private sector the most, and set about to privatize the program. The U.S. government also raised the prices for Landsat data in an attempt to recover an increasing share of its operating costs. Current Landsat revenues are an uncertain indicator of the value and future potential of the earth resources remote sensing market because such data has been provided more or less on the same basis as environmental satellite data. Moreover, governments have been providing potentially commercial Landsat-based services, at no cost, both as operational programs and as R&D programs. Thus prices and revenues have been kept artificially low.

Approximately one third of the Landsat data sales by the EROS Data Centre have been to the US government (mainly the Department of Agriculture). Non-US users account for another quarter to one third, industry another third, and the remaining 10 per cent or so is divided between state and local governments, individuals and academia. In US FY84, imagery sales (34,964 frames) amounted to $2,221,753, digital products (3,042 scenes) to $1,590,875.* Most industrial users classify much of their work as experimental. The fact is that land remote sensing has not been available long enough for a mature market to exist.

---

* EROS Data Centre - Customer Profiles of Landsat Data, and NOAA Satellite Programs Briefing, March, 1985.

While renewable resources (agriculture and forestry) represent the largest public sector uses of Landsat imagery so far, the oil and gas sector is the largest industrial user which employs the data to perform preliminary surveys prior to seismic exploration.

Factors that would improve the market for remote sensing, value-added services include:

- improved sensors with advanced or entirely new capabilities
- improved spatial resolution (better than 10 m.)
- stereo images
- radar sensors for all weather viewing (global coverage)
- specialized narrow spectral bands

All of these improvements are contemplated for future resource and environmental satellites of the late 1980s and 1990s. While they may improve the utility of Landsat-type data, the sheer quantity of data arising from such improvements presents a storage and a data processing problem. Improvements in storage technology, and in image processing and interpretation, must go hand-in-hand with improved sensor performance. The use of advanced computer techniques, both hardware and software, and the application of artificial intelligence and expert systems will be necessary in order to combine remotely-sensed data with other data in a user-friendly format. The provision of such data and information to relatively unsophisticated users will likely be the main push of the value-added market by the turn of the century.

3.5.5 Summary

While aircraft-mounted and in-situ sensors will always be an alternative to satellite sensors, the signal advantages derived from the broad overview from space, and the global coverage, place satellites in a unique position in the market for land, oceans and environmental data. Over the next 15 years that position will be strengthened by the application of new or advanced sensor and data processing technologies.

The end of the century will be characterized by a plurality of remote sensing satellites carrying optical and microwave sensors - some operational, others experimental. Each will be optimized to suit the requirements of its owners. At least two commercial polar orbiting satellites will be operating - EOSat's Landsat and France's Spot. The 20-month delay between the future failure of Landsat-5 (mid-1987) and its successor places Spot in a strong position to capture a large portion of the commercial raw data market in the late 1980s. Those users that rely on such data in an operational mode will be forced to pay the switching costs, and some are not likely to switch back when Landsat 6 comes on stream.

The large number of microwave environmental satellites coming into service in the late 1980s and early 1990s is staggering (six with SAR, four with Microwave radiometers). Fortunately there are differences in orbits, frequencies, special features and total sensor complement that tend to give each satellite a special role. These satellites are intended to be used for operational purposes, so that their replacements should be flying in AD 2000. By that year, most major nation's weather and environmental forecasting services will be employing numerical forecasting and will have integrated satellite numerical data and imagery into routine operations.

Value added services using remote sensing satellite data should be big business by the year 2000. The size and growth of this business will depend somewhat on how readily the gap in Landsat data can be filled with Spot data. Operational users would lose faith if a serious gap in data availability occurred. While government action has inadvertently slowed the introduction of value added services as a business (by essentially providing such services free), more recent governmment actions have been as a platform for space science, and as a servicing facility with manned interaction which will extend the life of future science missions.

Missions for the early 1990s include an advanced solar observatory, a large deployable reflector, an advanced x-ray telescope system and a space-based addition to the very long baseline radio interferometer network. Also planned is a Starprobe to fly within four radii of the sun's surface.

ESA's future programs, while autonomous do interlink with NASA's. It is based on four cornerstone programs:

1. The Solar Terrestrial program composed of about 2 medium-sized missions, which would contribute to the International Solar Terrestrial program of NASA and Japan.

2. A planetary cornerstone composed of a major project to visit primitive bodies of the solar system and bring back pristine material.

3. An x-ray astronomy cornerstone composed of a major project aiming at studies of the energy source of x-ray sources by high spectral resolution.

4, A sub-millimetre astronomy cornerstone, composed of a large telescope for studies of the physical characteristics of IR sources by means of heterodyne detectors.

The latter two cornerstones can be classified under the distant universe heading. In addition, ESA intends to support a number of smaller projects using an established competitive procedure. While ESA claims it will not need launch capabilities beyond those of the Ariane IV family, the Spacelab and Eureca (See Section 3.7) nominal orbits (28^{o}, 500 km.) can successfully be used by some disciplines.

As regards space station, European scientists have recently taken an essentially similar position to that of their American through the thick cloud layer that envelopes the planet - a task that will be complete by 1989.

In the 1985-89 time frame, the first of four new initiatives will be a Mars Geoscience and Climatology Observer which will probe the atmosphere, surface geochemistry, interior and climate of Mars on a global scale. This will be the first of a series of Planetary Observer Class missions using a modified "production-line" earth-orbital spacecraft bus. NASA also plans a comet rendezvous and asteroid flyby (using a Mariner Mark II, launched in 1990), a Lunar Geoscience Observer and a Titan Probe and Radar Mapper which will probe Saturn's largest satellite's atmosphere and surface features.

NASA's Solar System Exploration Committee has recommended a core program of missions to be initiated by the end of the century. It would involve the following missions:

Inner Planets:	Mars Aeronomy Observer*
	Venus Atmospheric Probe Observer
	Mars Surface Network Observer
Small Bodies:	Comet Atomized Sample Return Observer*
	Multiple Mainbelt Asteroid Orbiter-Flyby
	Near-Earth Asteroid Rendezvous Observer
Outer Plants:	Saturn Orbiter
	Saturn Flyby and Probe
	Uranus Flyby and Probe

---

* Candidates for potential ESA and European initiatives

ESA's first spacecraft to be sent on an interplanetary mission is Giotto, launched on July 2, 1985 by an Ariane I for an encounter with Halley's comet in March, 1986. The nucleus will be passed by only 500 km. Giotto is one of several international spacecraft planned to encounter the comet in 1986.

Two of ESA's cornerstone programs were cited in Section 3.6.2 above - a solar terrestrial program and a planetary mission to collect and return samples, more details of which can be found in Appendix 3. Other experiments are being planned by Japan and Germany.

The USSR has operated a series of active interplanetary programs. The most ambitious so far has been the Vega Venus lander program. Two spacecraft launched in December 1984 successfully deployed instrumented balloons into the Venusian atmosphere, and instrument packages that landed on the planet's surface. Vega 1 and Vega 2 are now on their way to a rendezvous with Halley's comet in March, 1986. The closest approach is expected to be in the order of 10,000 km.

The Soviets continue to be the dark horse in the space science race. Should they pull off a space spectacular over the next few years, the US plans over the following years could be altered significantly. Thus despite careful planning, such a possibility throws at least some elements of uncertainty into the AD 2000 space science scenario.

3.6.4 Earth and Atmosphere

NASA's program to study the earth and its atmosphere emphasizes the understanding of processes that effect earth's habitability, particularly its biological productivity, and air and water quality. The program involves coordinated observational, theoretical, experimental and modelling investigations, and the development of future observing technologies. The current program consists of:

- Landsat - Landsats 4 and 5 are now in orbit, and taken over by NOAA.

- Shuttle Imaging Radar - SIR-A and SIR-B have been flown on Shuttle; SIR-C is scheulded for 1987 will use multiple frequencies and polarizations.

- Multispectral Linear Array Sensor - a pushbroom scanner with on-board signal processing expected to fly in 1987.

- The Oceans - improved scatterometer data, research on spaceborne current sensors, measurements of chlorophyll concentration, the World Ocean Circulation Experiment and the Tropical Oceans/ Global Atmosphere Experiment.

- The Atmosphere - as a contribution to the First Global Atmosphere Research Program, NASA is developing an advanced temperature and moisture sounder whose performance could approach that of radiosondes, but with more complete spatial coverage.

- Mesoscale Processes - research from space on severe storms and local weather, the use of aircraft to test sensors such as the Doppler Lidar Wind Velocimeter and improvements in the application of GOES VISSR to numerical forecasting.

- Earth's Radiation Budget - The Earth Radiation Budget Experiment (ERBE) and observations from Nimbus 6 and 7, cloud research.

- Trace Species - measurement of major trace species in the troposphere using aircraft, and in the stratosphere and mesosphere using balloons and rockets; Shuttle measurements using the Imaging Spectrometer Observatory and the Atmospheric Trace Molecule Spectroscopy Experiment.

- Geodynamics - laser ranging and microwave interferometry are being used to measure motions of the earth's polar axis, variations in the length of the day, and motion and deformation of the earth's crustal layer. A laser Geodynamics Satellite, being built in Italy,is to be launched by Shuttle in 1987.

- Space Plasma Physics - has two thrusts: the study of large scale systems, and controlled studies of interactive processes. Current satellites include Dynamics Explorers 1 and 2, International Sun-Earth Explorers 1 and 2 for the first thrust; and the Active Magnetosphere Tracer Explorer (NASA, Germany and the UK) in conjunction with a Charge Composition Explorer, and experiments on board Spacelabs 1 and 2 for the second thrust.

- Global Biology - measures the influences of biological processes or global biochemical cycles through investigation of the aerial extent of land use and biomass, rates of change of biomass, biogenic gas fluxes; in-situ monitoring of ecological processes and interpretation of sedimentary fossils.

New initiatives in the 1985-89 time frame involve an Upper Atmosphere Research satellite, Shuttle-Spacelab payloads, the Ocean Colour Imager, a Tethered Satellite System (Italy has agreed to provide the satellite for an atmospheric tethered downward mission and a space plasma tethered upward mission), Topography Experiment for ocean circulation (TOPEX), improved scatterometer, Magnetic Field Satellite (Magsat-1), Geopotential Research and an International Solar Terrestrial Physics program.

During the 1990s, the earth studies program will continue investigations into the long-term physical, chemical and biological trends and changes in the earth's environment including earth's lithosphere, atmosphere, magnetosphere, land masses and oceans. It will also measure the impact of human activity. In-situ and space measurements will be made. The space measurements will require a space sation polar platform to support a variety of remote sensing instruments.

ESA's earth and atmosphere research program long-term objectives are to prepare for the establishment of operational systems, and to provide the necessary research tools. These objectives entail the development of experimental/preoperational systems, development of the user market, national and international program coordination and the fostering of a space supply industry. The planned program includes:

- ERS-1 define, develop and exploit the coastal, ocean and ice applications of remote sensing data, and increased understanding of coastal zones and global ocean processes; launch 1989 (2-3 year life)
- ERS-2 similar to ERS-1, to extend data stream to 5-6 years.
- Advanced Ocean/Met - an operational version of ERS - 1 and 2, but also covering polar-orbiting meteorological applications; 1996 launch.
- Advanced Land-1 - define, develop and exploit land applications of advanced, all-weather remote sensing data acquired with microwave sensors; 1994/95 launch.

As for ocean and ice applications, the intention is to set up before AD 2000 an operational, all-weather land application system, installed and operated by user entities (as the US has done with Landsat). ESA also intends to develop a second generation operational Meteosat to be launched in 1994 which would provide temperature and water vapour profiles for the earth's polar regions.

ESA's solid earth program focusses on geodynamics and the physical processes that are active in the interior of the earth and responsible for catastropic events on the earth's surface. Applications include geodesy, and petroleum and minerals exploration. The program includes:

- Popsat (Precise Orbit Positioning Satellite), a two-way microwave ranging system for determining, with the highest possible accuracy, positions of points on the earth's surface, and to measure present-day horizontal and vertical motions; 1992/93 launch, and a second in 1997/98.

Later experiments will utilize the Eureca platform (Section 3.7) to conduct research on the geopotential field, and to perform experiments on spaceborne laser ranging to monitor local and regional deformations in seismic areas in an attempt to forecast earthquakes.

Other countries' earth and atmospheric research programs mostly interlink with the NASA and ESA programs described above. By AD 2000, much of the space-based atmosphere and earth-related research can and will be performed from platforms which comprise the in-orbit infrastructure that will be created as a result of the US space station program.

3.6.5 Life Sciences

NASA's life sciences program concentrates its research on two interrelated disciplines: medical science and biology. Medical sciences will address problems that arise in Shuttle operations and those that might arise in space station missions. The research takes advantage of flight opportunities through the Shuttle astronaut program. The biological sciences aim at understanding the nature of life - past, present and future - and of its relationship to the environment and indeed to the universe. Understanding the origin, evolution and distribution of life and life-related molecules, on earth and throughout the universe, requires correlation of earth data with observations of extraterrestrial matter such as planetary surfaces and atmospheres, interstellar molecules, meteorites, comets and cosmic dust.

The current program in medical sciences research is concerned with certifying crew members, and maintaining their health and career longevity. Biological sciences research focusses on exobiology (the origin, evolution and distribution of life and life-related molecules on earth and elsewhere), biospheric research (the effects of biological processes on global dynamics) and gravitational biology (physiological responses to the full range of gravitational forces from microgravity to high-g accelerations).

The life sciences flight experiment program supporting both medical and biological research encompasses Spacelab flights (dedicated and shared), Shuttle mid-deck experiments and investigations on Shuttle-launched free-flying spacecraft. During the 1985-89 time frame, major program expansion will occur to support the presence in space of unprecedented numbers of humans associated with the space station. The research will include:

- medical care and health maintenance in space
- advanced crew support
- human performance in space
- mid-deck flight experiments
- space station module - phase 2
- biospheric research
- exobiology payloads
- search for extra terrestrial intelligence

In the 1990s, further space station and biospheric research is planned, a regenerative life support system will be developed for use on very long missions and Vestibular and Variable Gravity Research Facility will be developed.

ESA's life sciences research program, which is part of its plans for microgravity research, leads up to the utilization of the European space station Columbus. ESA intends to use flight opportunities on Spacelab and the unmanned Eureca platform in its life sciences experiments. Other countries utilize NASA and ESA facilities in joint programs, and France has taken advantage of its astronaut's presence on the USSR Salyut-7 space station.

3.6.6 Summary

Space science lies at the heart and core of every nation's space program for the simple reason that such research likely will only be funded by governments. Most other space activities have potentially more tangible commercial benefits, and their long-term destiny is either in the private sector or oblivion.

For the space superpowers, planetary and deep space exploration programs are a means of gaining prestige, and form an arena of competition between east and west. Any major and unexpected feat performed by one side will almost certainly generate an equal and opposite reaction in the plans of the other. Since the USSR does not publish its plans, as does NASA, there will always be an added measure of uncertainty in forecasting events far into the future.

Earth and atmospheric research, particular that which supports environmental forecasting, is of more immediate concern to all nations, and certainly more affordable to the smaller countries. Environmental forecasting - weather, catastrophic, natural events, ocean surface conditions, ice and ice movement - is of major importance to human safety and commerce. While not always quantifiable, the benefits can be identified. It can be expected that such research will continue as an international effort throughout the balance of this century, and into the next, at a level of effort which is not likely to alter appreciably over the next 15 years.

By AD 2000, the space science community, particularly the distant universe and earth-related interests, will be heavily reliant on Space Station and its associated spacecraft, which has become known as the In-Orbit Infrastructure (IOI). The ability to retrieve, repair, refurbish and reinstate a scientific payload in orbit is an irresistable feature (even for those scientists that initially spoke out against Space Station). The IOI itself will provide ideal platforms for some science experiments. Since IOI will be a significant part of the AD 2000 scenario, it is dealt with separately in the next section.

3.7 In-Orbit Infrastructure

3.7.1 Introduction

In 1984, President Reagan formally announced the decision to proceed with Space Station - a permanently manned satellite which is to be operational within a decade, to be used for "peaceful economic and scientific gain". The program is to be international. As the president said in his January, 1984 State of the Union message:

> "We want our friends to help us meet these challenges and share in the benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals".

The concept of a station in space began with Skylab which was flown by NASA in 1973-74 as the world's first manned space laboratory. It could house astronauts for up to three months at a time. The USSR began the Salyut series of orbiting stations in 1971, which they have continued to upgrade to the present day. US Space Station planning started in early 1982, and included the following objectives:

- a three-year detailed definition phase (5-10% of program cost)
- NASA-wide participation
- development funding in 1987
- initial operation by 1992
- initial cost $8 Billion, exclusive of operational or payload development costs
- extensive user involvement
- international participation (ESA, Japan, Canada)

Serviced by the shuttle STS, Space Station is a logical extension of the shuttle orbiter program. Several other spacecraft will be involved in the program including co-orbiting unmanned and man-tended platforms, a tethered platform, polar orbiting platforms, an Orbital Manoeuvering Vehicle (OMV) and later an Orbital Transfer Vehicle (OTV). The Space Station will be capable of servicing, refueling and repairing other spacecraft. All of such vehicles and services comprise what is being called the In-Orbit Infrastr-ucture (IOI).

Europe also contemplates the estabishment of its own In-Orbit Infrastructure, initially in collaboration with Space Station. The ESA Columbus spacecraft will be the vehicle, which later could become an autonomous European Space Station with related co-orbiting and polar orbiting platforms, forming a separate European IOI.

The following paragraphs describe in broad terms the planned US and European space stations, still in the early concept stages. An attempt is made to forecast likely AD 2000 scenarios when the space infrastructure will be the dominant focus for a significant proportion of space related activites.

3.7.2 The US Space Station Program

The principal guiding features of the design of space station include:

- to be continuously habitable
- shuttle dependent
- manned and unmanned elements
- evolutionary: growth through incremental addition, modification and replication
- maintainable and restorable to operational effectiveness in orbit
- modularity and commonality to minimize costs

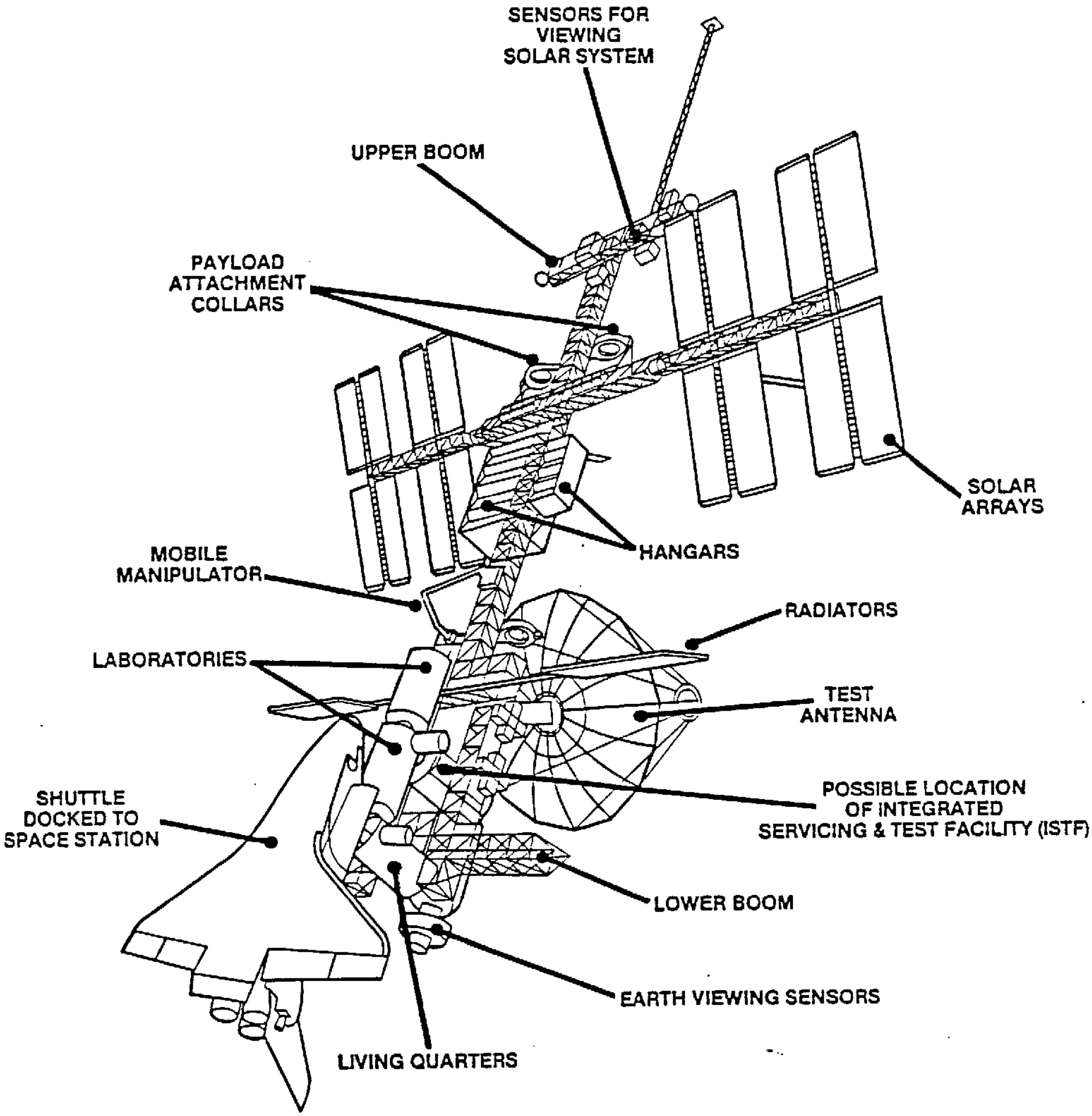
- appropriate mix of humans and machines: attempt to optimize the mix - many potential missions could be performed best by automated, free-flying spacecraft, with only periodic intervention by means of remote "telepresence".

An approved version of Space Station does not exist, but several configurations are being studied. Particularly favored is the 90,000 kg. Power Tower arrangement shown in Figure 3.4 - a 120 m. long spine of lightweight, high strength materials with a 65 m. cross-span holding 4 large silicon solar arrays (75 kw). The station will orbit at 500 km. altitude, serve as an initial base for a crew of six, and include five cylindical modules; two for living quarters, two laboratories and one for logistics.

During construction, the shuttle orbiter will carry the various station elements into orbit and help assemble the structure. Once the station is operational, the Shuttle will continue to bring supplies, fresh crews and equipment.

A space station advanced development program has been planned to provide the advanced technologies needed for an evolutionary station. Test beds at NASA field centres will be used in key technology areas such as power, life support and data management to support the research and testing required.

At present, space station definition and preliminary design (Phase B) studies are underway. Starting in April, 1985, they are to be completed by January 1987. They have four major components: supporting studies (user involvement), systems definition, advanced development program and technology. These four components evolve into the hardware development phase, Phase C/D, beginning in 1987. Early in 1986, a series of technical reviews will result in the definition of a Space Station baseline configuration to which the rest of Phase B analysis will be directed. These



THE SPACE STATION

Figure 3.4

reviews are major milestones in the definition and will include international partners. At the end of Phase B, NASA will begin the competition in the US for Phase C/D.

Mission requirements have been the subject of intensive study. Principal recommendations are for an initial station consisting of a manned base and an unmanned platform at an orbit inclination of 28.5o, an Orbital Manoeuvring Vehicle (OMV) operating in conjunction with the station, and an unmanned platform that would be derived from the Space Station design, operating at a polar or near-polar orbit, serviced by the Shuttle. Working groups examining missions for Space Station defined a preliminary set of 107 types of phased Space Station missions for the period 1991-2000, in the fields of science and applications, technology development and commercial applications.

Major specific missions planned for Space Stations include:

- a laboratory in space for R and D
- a permanent observatory for distant universe and earth observation
- a transportation centre where payloads and vehicles are stationed, processed and deployed
- a servicing facility, where payloads and vehicles are maintained, repaired and refurbished
- an assembly facility where large space structures and systems are assembled and checked out
- a storage depot where payloads and parts are kept in-orbit for later use
- a staging base for possible future projects, such as a permanent lunar base, manned misson to Mars, a manned survey of the asteroids, manned missions to geostationary orbit, or unmanned planetary probes
- a facility to enable manufacturing in space where the unique environment (particularly microgravity) enhances commercial opportunities.

The last mission on the above list creates a category of applications generally known as Materials Processing in Space (MPS), the subject of a later section, and a major application of Space Station by AD 2000.

As a customer-oriented facility, the Space Station will be available to countries whether or not they participate in the development phase. However, a nation with significant involvement in the development phase will have a role to play in the operation of Space Station. Present partners with NASA are ESA, Canada and Japan which will be involved in all phases of program development, use and operations*.

The ESA contribution relates to its Columbus program (described later) which includes the study of pressurized modules, unmanned payload carriers and ground support facilities. Canada is studying an integrated servicing and test facility, solar arrays and remote sensing applications. Japan is studying the concept of a multi-purpose experiment module.

Finally, the US National Commission on Space, which is developing a blueprint for the US civil space program for the next 20 years, has released some of its finding even though its report is not due until March, 1986**. The concepts being considered include the establishment of the infrastructure required for the initial manned exploration of the inner solar system, beginning with the construction of four space stations - one in low earth orbit, one in high earth orbit, one around the moon and one around Mars. They would be followed by more space stations in continuous

---

* R.J. Freitag, Director, Policy & Plans Office, NASA Space Station, NASA Develops Space Station, Space, Vol. 1, No 1 June, 1985; p. 20.

**Aviation Week, July 29, 1985, p.18

earth-moon and earth-Mars orbits to serve as a means of transportation between these bodies. Vehicles similar to the Appolo command and service module would be used to rendezvous astronauts to these stations. Such space stations would be considerably larger than the current Space Station, and serve more as space ports with astronaut quarters, refueling and tank farms, engine overhaul and testbed facilities, spacecraft assembly, mating, checkout and launch facilities for the recovery and refurbishment of spacecraft.

3.7.3 The European Space Station Program

After extensive study and careful consideration, ESA has decided to support the US Space Station through its Columbus program proposed initially by Germany and Italy, and now adopted by other European countries and ESA. Columbus is a pressurized laboratory complex, developed from the Spacelab module, for permanent use in space.

The proposed ESA baseline program over the next two decades is planned to be as follows: *

Phase 1: Based on Columbus, to secure the future by improving - through cooperation with NASA in the development and utilization of an international space station - manned flight capability, and by acquiring a capability for automated orbital operations.

Phase 2: Overlapping with the first phase, to develop the other elements of an autonomous European in-orbit infrastructure.

---

* ESA Council, Outline of a Long-Term European Space Plan, ESA/C (84) 46, Rev. 1 November 1984

The program contains three elements:

1. Columbus Program - Preparatory Program (Phase B) completed in 1986

   - Laboratory Module 1987-1992/93

   - Serviceable Platform 1987-1992/93 (possibly a Eureca Mark II).

2. Advanced Systems and Technology - re-entry and recovery techniques, rendezvous and docking, robotics and telemanipulation, life support and system studies for an autonoumous European IOI.

3. Development of the European In-Orbit Infrastructure - based on the above studies 1989 - beyond 2000.

The development of a European IOI will depend on answers to fundamental questions being studied: which commercial applications require the setting up of an autonomous IOI? What is the best compromise between human intervention and automation?

If human intervention is considered essential, then ESA can either use NASA's STS or develop its own. The Hermes manned spaceplane proposed by France to be launched by Ariane 5, is a proposed mini-Shuttle which could provide Europe with an independent means of transportation to Space Station, or its own IOI*.

It is clear that the Europeans ultimately want their own IOI, and see the NASA Space Station as a way of getting there. ESA has laid some very stringent requirements as necessary conditions

---

* Japan also has announced its intention, by the early 21st century, to develop its own Shuttle, to supply and service the IOI from Japan. Globe and Mail. August 9, 1985

for European cooperation with NASA on Space Station:

- be recognized as a step toward European autonomy for exploiting low orbit
- technological cooperation so Europe can develop necessary technology for an IOI in less time and at less cost
- European technical and financial management must remain in the hands of Europe/ESA
- conditions for European access to the complete Space Station system will have to be clearly defined, e.g.
  - freedom of access
  - freedom of utilization
  - European crew for European experiments
  - clearly defined financial conditions for use of Space Station
- no exchange of funds between NASA and ESA, which implies offsets for European industry.

It is not yet clear whether all these conditions can be met and, if not, which direction ESA might take. The decision has been taken to pursue the Columbus Preparatory Program, but the final decision to participate in the developemnt of Space Station will be taken in the fall of 1985. The decision to embark on the development of the autonomous in-orbit infrastracture will not be taken until the late 1980s. If ESA decides to proceed, the average annual cost will be in the order of 400 MAU/year.

3.7.4 Summary

By AD 2000, provided future US administrations do not reverse current plans, a US in-orbit infrastructure will be in place. It will include the basic Space Station, co-orbiting man-tended and automated spacecraft, satellites tethered to Space Station, a polar-orbiting unmanned earth-observation spacecraft service by Shuttle, and an OMV. In addition, it is likely there will be an Orbital Transfer Vehicle (OTV) to transfer crew and equipment to geostationary orbit and return. The number of man-tended and automated vehicles will depend on how rapidly the market will develop for on-orbit workspace leasing, particularly for research and production activities by organizations that do not have the financial resources to purchase a dedicated platform. This subject is dealt with more completely in Section 3.8.

By the turn of the century, depending on decisions yet to be taken by ESA, there is likely to be a European IOI as well. From the current literature, such an IOI will parallel the US Space Station development, including a polar orbiting earth observation platform.

The actual AD 2000 scenario for IOI is highly dependent on how rapidly commercial interests develop in space. These interests depend on how critical the microgravity environment will be to certain manufacturing processes. The next section deals with the processing of materials in space.

3.8 Materials Processing in Space

3.8.1. Introduction

The Shuttle provides, for extended periods of time, a laboratory environment in which the effects of gravity are very minute. While earth's gravity is weak compared with other physical forces, it influences many processes, often in subtle ways. Convection forces and the currents that result from them can cause disturbing effects to physical processes, and even the confinement of fluids can cause intolerable impurities from the walls of the container.

The microgravity environment of an orbiting body, which essentially is in free fall, provides freedom from such gravity-induced constraints thereby offering new dimensions in process control.

The combination of physical properties offered by space - microgravity, extreme temperatures and near vacuum - can be exploited for materials processing in space (MPS). MPS includes two kinds of activity:

- the use of space to obtain knowledge that can be applied to improve terrestrial processes, and
- the development of new products and processes that are possible only in space

The first of these functions would involve routine use of a space laboratory as a method of solving problems related to the processing of materials on the ground, where industry might be expected to pay at least a portion of the costs. For example, companies have expressed an interest in using space to investigate:

- combustion and catalytic reactions
- thermophysical properties of materials
- process models in the absence of gravity
- the role of convection in crystal growth
- small quantity production of unique materials
- the structure of cast materials (e.g. John Deere's plans)
- the effects of microgravity on molten metal and alloy mixtures

The present program plans of NASA and ESA are in support of the first type of activity which extend through the 1990s, and exploit the in-orbit infrastructure. They are described in the following two sections. The second MPS function is where the major returns can be expected - the actual production of materials in space. In large measure, such activities are dependent on the results of the first function. By the turn of the century, it is probable that a sufficient number of processes will be developed which cannot be duplicated on the ground, so that an entirely new industry likely will emerge by AD 2000. This conjecture will be explored in Section 3.8.4.

3.8.2 NASA's MPS Program

The goals of the Microgravity Science and Applications program are to investigate the behaviour of materials in a fluid state, and the effects of the behaviour of carrying out processes in the microgravity environment of space, to provide a better understanding of the effects and limitations imposed by gravity on processes carried out on earth, and to evolve processes that exploit the unique character of the microgravity environment of space to accomplish results that cannot be achieved on the ground.

The program concentrates on:

- materials sciences, including crystal growth solidification of alloys and composites, and containerless processing.
- physics and chemistry including fluid mechanics transport phenomena, combustion science, cloud physics, and critical phenomena
- biotechnology, including separation processes, suspension culturing and blood rheology

In order to implement the program, NASA has established an advisory/working group structure of research scientists and centres of excellence at various universities. With industry NASA has developed Technical Exchange and Joint Endeavour Agreements. The former mechanism allows a firm to work with NASA where there is no exchange of funds. It can use NASA's ground-based facilities - drop tubes, drop towers and aircraft

- at no cost, to determine if space testing is justified. The Joint Endeavour Agreement (JEA) allows an industrial firm and NASA to share the costs and risks of developing commercial space ventures. The firm is expected to provide the apparatus at its own expense; NASA provides a specified number of free flights in return for considerations such as data rights and use of the apparatus. If the venture turns out to be profitable, NASA is reimbursed for future flights.

Today, NASA has six ways of providing a microgravity environment for reseach and manufacturing:

1. Drop tubes/tower at Marshall Space Flight Centre and Lewis Research Centre (4 - 5 seconds)
2. KC-135 aircraft, which fly a parabolic flight trajectory (5 - 25 seconds, repeats per flight)
3. Sounding rockets (several minutes)
4. Mid-deck space on the Shuttle (several days)
5. Various types of payload support structures, mounted in the Shuttle cargo bay (several days)*
6. The Long Duration Exposure Facility (LDEF) (several months)-a passive frame on which materials can be mounted for prolonged exposure to space.

The current program includes ground-based investigation, Mid-Deck experiments and Materials Experiment Assembly experiments. The ground-based program includes such activities as the study of convection in crystal growth, non-gravitational phase separation mechanisms, containerless processing, and bioseparation processes.

Mid-Deck experiments provide relativelty long term microgravity

---

*Facilities such as Spacelab are potentially available. Also several firms offer getaway Special Canisters (GAS-Cans)for attachment to the Shuttle, which can house small, self-contained experiments.

TABLE 3.4 U.S. MATERIALS PROCESSING INSTRUMENTS

Apparatus	Shuttle Location/Carrier	Availability
Directional Solidification Furnace	Mid-Deck	Ready Now
Isoelectric Focusing Experiment	Mid-Deck	Ready Now
Acoustic Containerless Experiment System	Mid-Deck	Ready Now
Electrophoresis Equipment Verification Test	Mid-Deck	Ready Now
Continuous Flow Electrophoresis System	Mid-Deck	Ready Now
Monodisperse Latex Reactor	Mid-Deck	Ready Now
Droplet Combustion Experiment	Mid-Deck	Planned (1986)
Particle Cloud Combustion Experiment	Mid-Deck	Planned (1986)
Single Axis Acoustic Levitator	Orbiter/Materials Experiment Assembly	Ready Now
General Purpose Furnace #1 (Isothermal)	Orbiter/Materials Experiment Assembly	Ready Now
General Purpose Furnace #2 (Gradient)	Orbiter/Materials Experiment Assembly	Ready Now
General Purpose Furnace #3 (Gradient)	Orbiter/Materials Experiment Assembly	Ready Now
General Purpose Furnace #4 (Gradient)	Orbiter/Materials Experiment Assembly	Ready Now
Single Axis Acoustic Levitator-II	Orbiter/Materials Science Laboratory	Planned (1984)
Three-Axis Acoustic Levitator	Orbiter/Materials Science Laboratory	Planned (1985)
Directional Solidification Furnace-II	Orbiter/Materials Science Laboratory	Planned (1984)
Advanced Directional Solidification Furnace	Orbiter/Materials Science Laboratory	Planned (1986)
Isoelectric Focusing Experiment	Orbiter/Materials Science Laboratory	Planned (1985)
Electromagnetic Levitator	Orbiter/Materials Science Laboratory	Planned (1984)
Acoustic Containerless Experiment System-II	Orbiter/Materials Science Laboratory	Planned (1986)
Fluids Experiment System	Orbiter/Spacelab 3	Ready Now
Vapor Crystal Growth System	Orbiter/Spacelab 3	Ready Now

optical fibers, highly specialized alloys and precision latex spheres. Other applications may emerge as unforeseen results are obtained.

It should be noted that space on board Shuttle for MPS experiments is becoming increasingly scarce. The demand for mid-deck accommodation and even Getaway Specials from a broad range of US and other users has developed very rapidly in recent months. New facilities will need to be created if the current demand is to be met - at least until space station achieves it initial operational capability (IOC) in the mid-1990s.

3.8.3 ESA's MPS Program

ESA envisages that the material and life science communities will be the major users of a future low earth orbit infrastructure (i.e. Columbus), and thus stresses the importance of a strong MPS research program paralleling the development of Columbus. Its plans cover the use of the Spacelab manned laboratories, and the unmanned platform Eureca.

ESA's current MPS program focuses on the Eureca free-flyer. Studies on a free-flyer culminated late in 1984 with the decision by MBB/Erno to proceed with development of the Eureca European retrievable carrier. Deployed from the Shuttle cargo bay by the manipulator arm, Eureca will propel itself to a 500 km. orbit where it will remain for six months before returning under its own power to rendezvous with Shuttle in low earth orbit. After each mission, Eureca will return to earth for refurbishment and re-launch. On board Eureca for its first mission in November 1987 will be an ESA, German and Italian payload of microgravity experiments, plus an inter-orbit communications package, forerunner of the planned European data relay system, DRS-1. ESA's long-term

2. Man-Tended - where initial manual set-up is required, but the process can be left untended while it runs

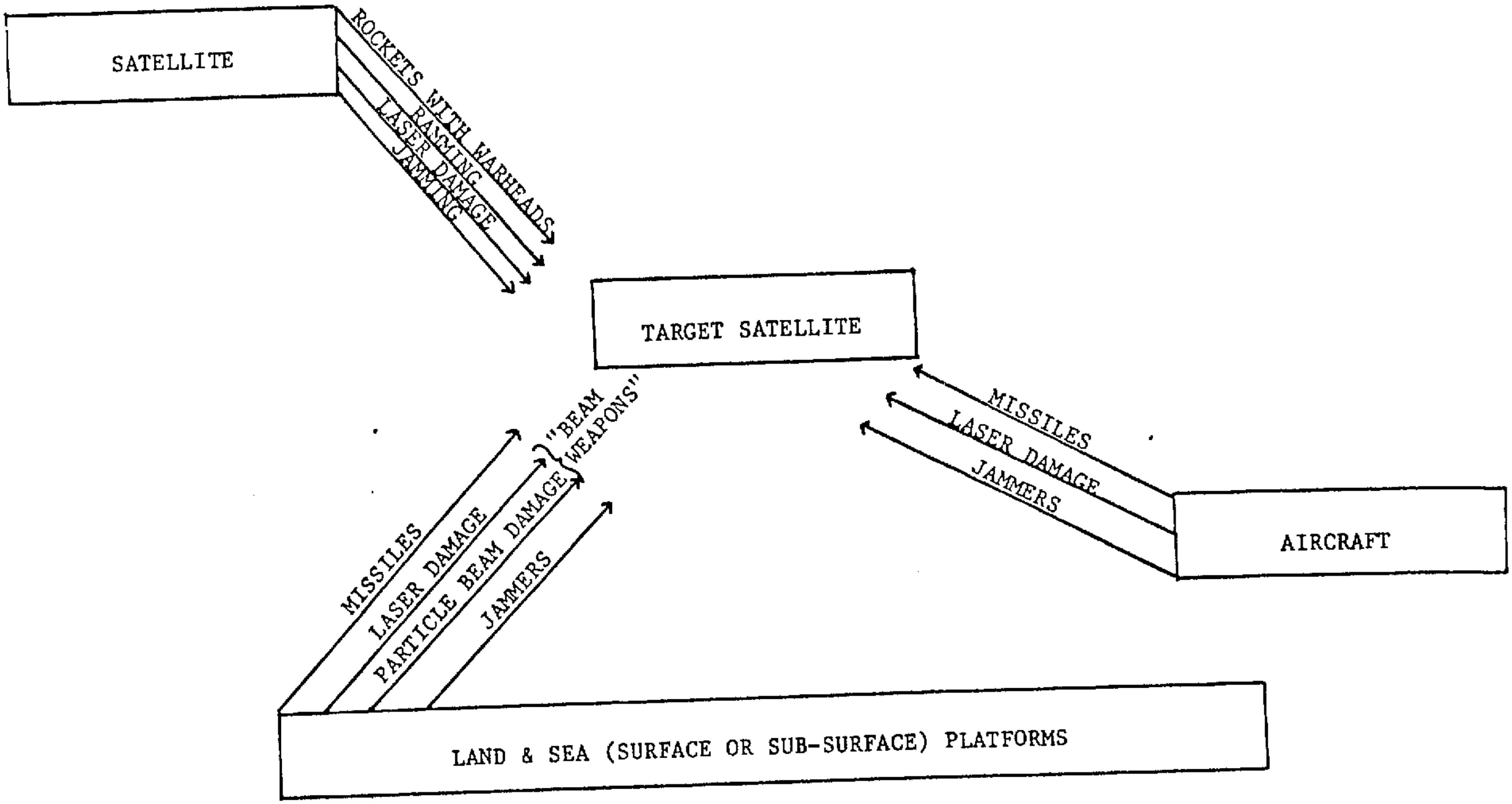
3. Automated - free-flying facilities, totally automatic

Each of the three types represents a degree of maturity of the process where permanently manned workspace is needed at the early stages of development, man-tended during early production and automated for straight-forward, high quantity production. One disadvantage of the permanently manned facility is that the presence of man, and the small motions so created, results in a less than perfect microgravity environment, and may be unacceptable for some kinds of processes that are extremely sensitive to small disturbances.

In addition to the microgravity environment, the most common requirement for all MPS payloads is the available power for MPS. Power can be used as a currency in assessing the potential cost-comparative advantages of different MPS workspaces. The Fairchild Leasecraft, the best-advertised commercial system at present, ranges in leasing costs from $5 to $10 Million per kilowatt year. Clearly such figures also will depend on the size and mass of MPS equipment, but they do provide order of magnitude values that have been used to compute revenues such as in the Centre for Space Policy studies which project an AD 2000 range of $0.5 to $2.5 Billion for workspace leasing.

3.8.5 Summary

Since both NASA and ESA have mounted extensive MPS research



PLATFORMS ON WHICH ANTI-SATELLITE WEAPONS CAN BE SITED

FIGURE 3.5

(TDRSS), its deep space network and some overseas stations not covered by US-based locations. By the turn of the century, they will have acquired greatly expanded data handling capacity into the high Gigabit regime. ESA is planning its own system (DRS-1) to support the European in-orbit infrastructure, where there will be regional ground receiving stations and an expanded Earthnet system. Over the next 15 years, it can be expected that a rapidly evolving and growing network of remote sensing ground stations will be put in place to take advantage of incresing numbers of resource satellites in orbit during the 1990s (future Landsat, Spot, ERS-1, Radarsat, JERS-1, DMSP, N-Ross, etc.)

Payload processing involves the integration and testing of spacecraft prior to launch, including the necessary major capital facilities. Also, by the year 2000, it is likely that there will be a commercial spacecraft payload processing market centered at the two US launch facilities (Cape Canaveral, Fla. and Vandenburg AFB, Calif.). The related industry will perform final assembly, test and integration services at the launch site for Shuttle cargo bay payloads, including the preparation and harvesting of materials for MPS applications.

In addition to launch-site facilities and services, there are the major capital installations required by the supply industry. They include the large clean-room and payload integration and test facilities, and the major environmental testing installations needed to handle payloads of the size that can be accommodated by the Shuttle and other launch vehicles in service during the 1990s. Such facilities will involve major capital expenditures not only to establish them initially, but also to maintain them at the current state-of-the-art.

The space insurance industry began in 1965 with the first policy written for Intelsat. Since then, the industry has blossomed to where several billions of dollars are underwritten yearly, dominated by London underwriters which have captured 70 percent of the market.

Several types of insurance are available:

- pre-launch insurance - from shipment to ignition
- launch insurance - from ignition to being functional in-orbit
- life insurance - against failure in-orbit to end of normal life
- third-party liability insurace - paying compensation to persons or property damaged by a space object

While communication satellites have been the principal source of insurance business so far, in future as increasing numbers of commercial activities take place in space, the opportunities for insurance underwriting will expand accordingly. In particular, privately-owned remote sensing satellites and commercial MPS activities will be the principal market over the next 15 years, but commercial launch vehicle operators may also add to the market. The Center for Space Policy estimates AD 2000 space insurance revenues ranging from $0.3 to 1.6 Billion.

CHAPTER 4

IMPACT OF THE AD 2000 WORLD SPACE ENVIRONMENT ON THE CANADIAN PROGRAM

4.1 Introduction

On March 20, 1985 an Interim Space Plan for Canada was announced by the Minister of State for Science and Technology. The plan covers the year 1985-86 and includes:

- acceptance of the invitation of the President of the United States to join the Space Station program
- support for the implementation of a commercial Mobile Communications Satellite system (MSat)
- continued development of a remote sensing satellite for resource monitoring and ice navigation (Radarsat)
- a commitment to maintain and develop Canadian capabilities in space

The interim plan funding is as follows:

	1985-86
Technology Development	$60.3 Million
Remote Sensing	73.5 "
Communications	38.1 "
Space Science	22.2 "
	$194.1 Million

Technology development includes $8.8 Million in 1985-86 for Space Station project definition. It also includes the development of new technologies and products in Canadian industry, the provisions of national facilities and the Canadian Astronaut Program. Remote Sensing includes Canadian participation in the Earth Resources Satellite program of ESA, and the development in Canada of the Radarsat program. The Communications program consists of the development and demonstration of new applications of communication satellite technology, such as MSat and SARSat. Space Science activities centre on studies concerning space plasma physics, and upper atmospheric physics and chemistry.

In Chapter 3, the world space scenario at the turn of the century was described in order to set the stage for generating a Canadian space strategy. The present chapter assesses the impact of the AD2000 environment on current Canadian space plans. In particular, it attempts to identify threats and opportunities that should be considered in the development of the long-term Strategic Space Plan. Such an impact evaluation could then be used to assess the strengths and weaknesses of the current Canadian capabilities in industry, universities and government.

The analysis should lead to the identification of niches and resources that must be strengthened in order to sustain momentum, capitalize on opportunities and thereby achieve objectives.

It is convenient to employ the following Canadian space program structure:

a) Satellite Communications
b) Remote Sensing
c) Canadian Space Science
d) Space Station
e) Materials Processing in Space
f) National Defence
g) Technology
h) Support Programs

The following sections deal with each of the above program elements in turn. Chapter 2 of this report covers current programs, to which the reader is directed for a general description of the programs referred to in the paragraphs that follow.

commercial satellite communications in Canada. Telesat is jointly owned by the Canadian government and Canadian telecommunications carriers. Among the services provided by Telesat are the transmission of network television, telephone conversations and commercial data traffic. Telesat is considered to be a carriers' carrier and is subject to regulation by CRTC.

The government has held the view that Telesat is a complement to and not a competitor with existing telecommunications carriers, and encourages a close association to ensure an efficient and effective integration of fixed satellite and terrestrial facilities. A connecting agreement was approved in 1977 when Telesat commited itself to the construction of a new series of fixed satellites (Aniks B, C and D), and the Trans Canada Telephone System, TCTS (now Telecom Canada) undertook to provide financial and utilization guarantees to Telesat. In 1981 Telesat was permitted to lease satellite channels directly to broadcasting undertakings and thus become a retail-level carrier, in addition to its traditional role as a wholesaler to approved carriers such as CN/CP, Telecom Canada and BC Tel.

In recent years, with the coming advent of coast-to-coast fibre optic cables, the trend among the telephone companies (Telcos) is to use fixed satellite services less and less. For example, Telecom Canada now leases 4 K_u-Band transponders on Anik C-3 - a contract that extends out to 1998. While the capacity is 1350 voice circuits per transponder, only 800 are being utilized at present, and all of these will be transferred to fibre within the next 2-3 years. After 1989, K_u-Band will not be used in the Canadian telephone message network.

While there may be some room for expansion of FSS in broadcasting (for centres not served by fibre), major broadcast trunking is also likely to transfer to fibre. Thus, Telesat must turn to business applications for growth. While this market is still small in Canada, its development in the US suggests that similar growth could be generated in Canada under perhaps more deregulated circumstances.

A major issue is emerging as to the viability of the FSS market over the next 15 years in Canada. The broadcast trunking market is insufficient to justify more than a minimal service, and currently the growth of the business market is, at best, uncertain. Such circumstances place severe financial pressures on Telesat Canada. Its current settlement payments from Telecom Canada (part of the 1977 connecting agreement) cease after 1987, and revenues from sources other than the Telcos are expected to make up the difference. By 1990, Anik D-1, and shortly afterwards the Anik-Cs, will reach their expected end of life and will need to be replaced. Aniks E and F, respectively, will replace them, and procurement processes must be started in the fall of 1985. There may be one dual band or two single band satellites, based on studies presently underway.

The strong economic pressures on Telesat will place stringent price constraints on Anik E/F. Telesat will be looking for the lowest possible capital cost per channel. The question again arises - can Telesat afford to pay the premium for Canadian content that inevitably must accompany the selection of a Canadian prime contractor.

While Canada (Spar Aerospace) primed Anik D, Spar supplied the payload but subcontracted with Hughes Aircraft Co. (HAC) for the HS 376 spacecraft bus. Whether, in future, it is HAC or some other US bus manufacturer, the cost of a Canadian prime contractor subcontracting for a US bus almost certainly will be higher than if both payload and bus were purchased from a foreign supplier.*

If Canada is to retain a prime contracting capability - a purpose considered to be congruent with the objectives of the current Canadian space program - then a means must be found for covering the costs of Canadian content for Anik E/F without directly encumbering Telesat Canada with an additional burden it cannot afford.

Should Anik E/F not be awarded to a Canadian prime contractor, the probability of achieving the prime role on future offshore communication satellite procurements like BrasilSat would be extremely small. The third world market for a Canadian/US satellite supplier team is most promising, assuming Canada retains credibility by continuing to prime its own domestic satellites.

This issue is central to any long-term Strategic Space Plan. The survival of a Canadian prime contractor capability also will impact Canada's role in MobileSat, remote sensing (Radarsat), Space Station, materials processing in space and possibly national defence.

---

* While the development of Canadian bus may, on the surface, appear to be a strategic option, the associated development and updating costs in relation to the _accessible_ market are prohibitive, and financial returns unattractive.

4.2.3 Mobile Satellite Services - MobileSat (MSat)

The opportunities and threats surrounding MSat evolve from the AD 2000 scenario when it is envisaged that at least three such systems will be in operation - N. America (US/Canada), Europe and Japan. Other regional systems may well be underway by then. Opportunities for Canada thus arise from the N.American market, and from other regional systems where severe competition can be expected.

The MSat concept emerged from a series of studies initiated by the government between 1980 and 1982, to investigate the feasibility of extending mobile and basic communications services to the remote and rural areas of Canada including the north and the 200-mile offshore limit. These Phase A studies showed that a satellite-based mobile communications system is the least cost method of achieving this objective relative to terrestrial or fixed satellite alternatives. The establishment of such a service would meet a social need for those not presently served with reliable communications, and also remove a barrier to Canadian resource development in remote areas. MobileSat showed the potential to be a sound commercial undertaking.

One technology competing with MSat is the expansion of mobile telephone services to rural areas by some regional telephone companies, particularly in the Atlantic and western provices. Other competing technologies include INMARSat and fixed thin route service. INMARSat overlaps with MSat in coastal waters, but at higher costs. Fixed Satellite thin route service is an alternative which is warranted where traffic and data rates are sufficently high that they would place a strain on MSat.

However, the major threat to MSat is the issue of system financing. According to the DOC news release of Mar. 20, 1985, the "expected investment from the private sector in Canada is over $400 Million". DOC has already spent $19 Million on MSat over the past 4 years. The release stated that once the system has been established, it is expected to generate over $2.4 Billion of total sales for Canadian manufacturing industries and service providers by AD 2000, and create 1600 continuing high technology jobs.

The MSat Phase B commercial viability study, conducted by Telesat Canada, concluded that the preferred system approach for service introduction includes Canada/US cooperative business arrangements. As stated in Section 3.3.4, there are 12 MSat applications before the US FFC, and a selection is not expected before early 1986.

From the satellite operator viewpoint, MSat is commercially viable only over two generation of satellites. The first generation is only marginally profitable, and in fact does not show a positive cash flow until four years after its launch, just when the second generation MSat is scheduled for launch. With such a long time span before significant return, it is virtually certain that the government will have to intervene in some tangible fashion if there ever is to be a Canadian MSat. Further study may show ways in which the return on investment can made be more attractive for private sector financing. Also there may be other approaches that reduce the risk.

The MSat ground segment shows promising market opportunities for the supply industry.* The first generation MSat will provide

---

*DOC Discussion Paper on the Industrial Strategy for the MSat Ground Segment, MSat Project Office, March 1985.

a variety of services to approximately 40,000 Canadian users - principally users of mobile telephone service (MTS), mobile radio service (MRS), mobile data services (MDS), and paging services. The types of equipment required include:

- land vehicle terminals; two-way voice and data, one-way data and paging
- MRS radio sets; full and half duplex
- mobile antennas; low-gain (4 dbi) and high-gain (8 dbi) steerable versions
- SHF gateway stations to interface with the Public Switched Telephone Network
- SHF base stations (5m. dish) for major dispatch users
- UHF base stations; portable with fixed, high gain antennas
- variety of equipment such as pagers, message terminals, data relay platforms, fixed UHF receivers

The potential total domestic market by the year 2000 should be in excess of $415 Million (1984$); however, competition will be fierce. The usual forms of government support would be available to the Canadian supply industry; but DOC intends to mount a special effort and strategy involving the selection of preferred suppliers which, with government support, will proceed to establish suitable product designs, marketing plans, product development and a production capability.

At the present time, there are some critical uncertainties concerning Sat. Perhaps the most critical is the outcome of the present FCC evaluation, and the relationship that can be established between Telesat, the US operator and the satellite supplier(s).

Canadian participation means Canadian financing which, as suggested, almost certainly involves further government investment or guarantees. Of course if Telesat does not proceed on MSat, Canadian service could be leased from the U.S.

While Canadian and US satellites do not need to be identical, they should have common elements so that the two systems are compatible. If the Canadian and US suppliers actually join forces, total costs should be less, and financial barriers could be lowered. Such an arrangement is predicated on the continued existence of a Canadian satellite supplier - a question that depends on whether or not Anik E/F is sourced in Canada.

Three of the prospective operators of MSat in the US have filed proposals at FCC to operate position location services in conjunction with MSat. A fourth applicant, Geostar Corp., would be independent of MSat. Such applications open up the question as to whether the Canadian market is ready for a commercial positioning service. If so, is it appropriate to be offered in conjunction with MSat?

The US studies show a very strong market for such services developing over the next decade. It is not obvious that Canada has the same needs. However, it might be looked upon as an intrusion of Canadian sovereignty if a US firm were to provide positioning services to Canada, especially if it were from a US base. To the writers' knowledge, no studies of this question have been conducted in Canada, and we consider it to be an issue which, for the moment, falls into the communication satellite category.

4.2.4 Direct-to-Home Broadcast Satellites (DBS)

As with MSat, DBS has been studied extensively by DOC.*
In April, 1981, the need to determine the place for DBS in improving

*Direct-to-home Satellite Broadcasting for Canada, Dept. of Communications June, 1983 surveys, the total direct-to-home market in Canada by 1996 is forecast to be up to 2.5 million households. Studies conducted by DOC suggest that the Canadian market is commercially viable; however, it is another matter for industry to concur and put up the money for financing.

The DOC studies point out that the effective implementation of a Canadian DBS system would require an appropriate policy and regulatory environment, taking into account:

- the role of DBS
- its financing (public or private)
- the institutional arrangements for the DBS system
- the programming to be provided by DBS and its cost
- the size of the DBS market
- the impact of DBS on the existing broadcasting system
- the impact of US DBS systems on Canada

A significant factor inhibiting the introduction of DBS in the US at present is the availability of sufficient program material at affordable prices. However, other countries such as Japan, Europe (Eutelast), France, Germany and the UK plan or now operate DBS systems. The AD 2000 scenario suggests a very strong space and earth segment DBS market on the assumption that the above policy issues can be resolved.

Currently DBS is being studied by Telesat Canada and Canadian Satellite Communications Inc. (Cancom).* The results of the

*Cancom is a national service using Anik D to deliver a package of radio and television program signals to affiliates in isolated communities.

study will determine the near-term fate of DBS in Canada. A DBS service could be launched immediately, using the spare capacity on the Anik Cs. Should DBS be shelved for say 5 years, a possible result of the study, then the Canadian earth segment industry would lose a domestic market with its potential leveraging action into the international markets now beginning to take form.

4.2.5 Summary of Canadian Satellite Communications Issues

The issues may be summarized as follows:

1. The viability and size of the future fixed satellite service transponder leasing market in the presence of competition from fibre optics including any inhibiting regulatory constraints;
2. Recognition and means of covering the extra cost of Canadian content, and the selection of a bus (Canadian prime contractor partner) for Anik E/F;
3. The maintenance of a satellite prime contracting capability in Canada;
4. Ability of Canada to team with the US FCC's winning MSat applicant;
5. Public vs private financing of MSat;
6. The future of DBS in Canada;
7. The means whereby a Canadian earth segment industry can be made internationally competitive through leverage from the Canadian program;
8. The provision of a commercial positioning service by a US or Canadian operator;

4.3 Remote Sensing

Spearheading Canada's remote sensing activity since 1970 is the Canada Centre for Remote Sensing (CCRS) within the Department of Energy, Mines and Resources. Many provinces and regions have subsequently established their own centres (such as the Ontario Centre for Remote Sensing). Also there are specialty centres dealing in discipline areas such as forestry and ice reconnaissance, usually associated with a federal government department. The industrial structure consists of a supply industry covering space and ground segments (e.g. Spar Aerospace, MacDonald Dettwiler, Canadian Astronautics), image processing equipment (e.g. Dipix, Perceptron) and value added services (e.g. Intera, F.C. Bercha). Universities such as Waterloo and Laval have strong academic and research programs in remote sensing. Thus the Canadian remote sensing community comprises an infrastructure of government, university and industrial institutions that has been forming over the past 15 years, and has achieved a measure of stability.

In respect of remote sensing from space, CCRS continues, through a contractor, to operate a ground station at Prince Albert, Sask., which has been upgraded to receive thematic mapper (TM) data from Landsats 4 and 5, and possibly later data from the French Spot satellite. A second ground station is being installed at Gatineau, Que., near Ottawa, to receive Spot data. Later it is likely that ERS-1 and Radarsat data will be received at Gatineau, and possibly also at Prince Albert. Gatineau will be a receive-only station; processing will be carried out at Prince Albert. When Landsat is taken over by EOSat, it is not yet known how arrangements will change. It is likely though that user fees and royalties will increase.

The main thrust of the future Canadian program in space remote sensing is toward active and passive microwave systems. The ability of microwave radiation to penetrate cloud cover and darkness is particulary revelant to Canada and Canadian arctic conditions. The MSS and TM sensors on Landsats 4 and 5 operate in the visual and infrared regions, and so are incapable of penetrating cloud. For many applications, the occurence of cloud cover at critical points in the imagery can render it useless.

Following NASA's Seasat program, and after further study, CCRS was authorized to proceed with the Phase A and now Phase B program definition studies of Radarsat - a Canada/US/UK remote sensing satellite to be launched by Shuttle in 1991. The satellite will carry four sensors:

1. C-Band synthetic aperture radar (SAR)
2. Scatterometer (N-Ross type)
3. Advanced Very High Resolution Radiometer (AVHRR)
4. High-Resolution optical push-broom scanner (MOMS derivative)

While Canada's CCRS carries the lead on Radarsat (Spar Aerospace is the prime contractor), other countries will make major contributions. The US is providing the scatterometer (JPL), the AVHRR (NOAA) and the Shuttle launch (NASA). The UK Dept. of Trade and Industry is providing the baseline olympus bus (British Aerospace).

The Canadian needs are for ice, iceberg, ship and ocean information over the arctic and coastal economic zones, and for crop, forest, hydrologrical and geological mapping over the provinces and territories. The satellite will also provide global wheat crop assessments, global marine wind information, and the first radar stereo-geological map of the world.

As pointed out in Section 3.5.3, during the 1990s there will be a plethora of earth observation satellites carrying sensors that, on the surface, appear to duplicate those of Radarsat. Such duplication may well be an issue, so that it is of value to examine the Radarsat sensors in more detail.

It is important to emphasize that Radarsat is intended to be part of an operational system involving a network of users. They include the AES - both meteorological and ice forecasting services, the offshore transportation and exploration sectors, oceanographic forecasters, the agriculture and forestry sectors, water resource managers, etc. ESA's and Japan's earth resource satellites, ERS-1 and JERS-1 respectively, both of which carry SARs, are essentially experimental in their purpose.

The Radarsat C-Band SAR will cover a 140 km. swath, but with its multiple beam switching capability, has access to a 500 km swath and can be used to produce stereo images. ERS-1's C-Band SAR is of lower performance, covers only an 80 km. swath, and has no stereo capability. JERS-1's L-Band SAR is in a wavelength band less suitable for ice reconnaissance and Canadian needs.

An N-ROSS type scatterometer is comparable to the instrument employed in Seasat. Used for measuring sea surface wind and wave volocities, it possesses a more complex beam structure and improved operating characteristics over the Seasat version. When coodinated with N-ROSS and possibly ERS-1 (which can operate its SAR in a wind mode), more complete and frequent global ocean coverage can be provided than with one satellite alone.

The AVHRR instrument provided by NESDIS is a 6-channel, low-resolution (1.1 km.), wide swath (2940 km.) system. It will be used in conjunction with the high-resolution optical sensor for agrometeorological purposes, specifically to provide precipitation and soil moisture condition data for global crop monitoring purposes. The data also should be of use to AES in filling gaps in data sets it receives from the operational NOAA satellites.

The Radarsat Optical Sensor (ROS) is a high-resolution (30 m.), push-broom scanner with a 400 km. swath in 4 wavelength bands (approximately 4 times the swath of Landsat's TM). It is a derivative of MOMS (Modular Opteolectronic Multispectral Scanner), developed by the German company MBB, and flown in an early Shuttle mission (SPAS package). This instrument's main purpose is for global crop monitoring, but it can serve other applications similar to those of the Landsat TM, thereby increasing the likelihood of acquiring cloud-free images at any particular location.

Radarsat is the first satellite to be designed specifically to be serviced in orbit. Should a problem develop at any time during its life in orbit at 1000 km. altitude, it can be directed down to the Shuttle orbit at 240 km., captured by the Canadarm, and berthed in the shuttle bay on a special servicing fixture. There units can be serviced or replaced and propulsion tanks re-charged so that it can be returned to its 1000 km. orbit to resume service. Otherwise it could be returned to earth for complete refurbishment. In this way the life of the satellite can be increased from 5 to 10 years.

Radarsat will be the first satellite designed to be used with NASA's Orbital Maneouvering Vehicle (part of the Space Station IOI). It will accompany Radarsat in the Shuttle cargo bay and be used to ferry the satellite to its operational altitude.

In his way, Radarsat's fuel supply needs are reduced, since it has to carry only the fuel required to return to Shuttle orbit for its servicing cycle.

Radarsat will require an advanced, high-throughput digital data processor in its ground segment, to be provided by MacDonald Dettwiler & Associates (MDA). The company has gained considerable experience in this area through its work on the development of the ground processor for Seasat, and as prime contractor for the ground segment of ESA's ERS-1, including the development of the fast delivery processor. MDA has proven its ability to export such technology by its record of sales of Landsat ground stations throughout the world.

From the foregoing, it is evident that Radarsat carries unique mix of sensors especially tailored to meet Canadian needs. While data sets from other satellites operating in the 1990s also will be useful to Canada, Radarsat provides to Canada quaranteed access to data it needs, and the necessary freedom to control the satellite in accordance with Canadian priorities.

Canada's Atmospheric Environment Service (AES) is becoming a major user of US meterological satellite data. In particular, data from GOES, the NOAA series and Nimbus 7 has been used experimentally, and is now slowly being integrated into the forecasting processes. Interest has been growing in the use of passive microwave (radiometer) data, currently being received from Nimbus 7. As described in Section 3.5.3, the SSM/I sensors on DMSP and N-Ross can provide operational data sets which could be employed by AES in its numerical forecasting processes, depending on the results of research currently in progress.

In summary, for remote sensing the central issue over the next 15 years is simply sovereignty. The trend among the developed nations is to create national and regional space remote sensing programs that are totally self-serving. The USA, Japan, ESA, France, Brazil, India, China and, not least, the USSR all operate or plan to put in place earth observation satellites between now and the end of the century.

Canada has its own sovereign interests to preserve. It was the threat that other nations could acquire data on Canadian renewable and non-renewable resources ahead of Canada that spirited the creation of CCRS and the Canadian involvement in Landsat. The Radarsat program grew from a concern over arctic sovereignty. Now it is intended to serve a broader set of purposes, embodying agricultural economic interests, as well as its sovereignty role in ice reconnaissance which provides an arctic "presence".

Technical challenges and opportunities centre on the new, narrow band sensors such as the High Resolution Imaging Spectrometer (HIRIS) which may have as many as 196 10 nm. bands in 30 m. pixels with a 50 km. swath width, planned for the Space Station polar platform. Such sensors need data handling facilities operating in the Gigabit per second range, and storage measured in Terabits. The high volume of data involved in geocoding, sorting, and pattern recognition functions suggests the need for automatic techniques and the use of artificial intelligence.

A further remote sensing opportunity is the polar platform of NASA's space station program. The ability to upgrade the sensor components of Radarsat's payload matches closely with the NASA plan to launch a number of unmanned polar-orbiting earth observation platforms. They will be serviced by Shuttle and have their instruments changed from time to time. Designing Radarsat for in-orbit servicing enables Canadian industry to gain early experience in the new repair technology that forms an important part of the proposed Canadian role in Space Station.

Finally, the plethora of satellite data sources beginning in the late 1980s offer opportunities for the value-added service industries. The future viability of such activities will be highly dependent on government policies in respect of cost recovery objectives. The rate of cost recovering is the key issue. If data products are priced high, corresponding to an expected high rate or recovery, the market may not develop sufficiently. The price elasticity for satellite data products is not well enough understood now to be able to establish a price/demand relationship. The process of price optimization to maximize the rate of recovery needs careful study. The development of a strong and healthy value-added industry, which purchases data products, is an objective that must be achieved before any reasonable rate of cost recovery is possible.

4.4 Canadian Space Science

The presence of the magnetic north pole within Canadian sovereign territory has placed an obligation on Canadian scientists to focus a significant research effort on auroral phenomena, and other interactions of the earth's magnetic field with the upper atmosphere. The Canadian space program originated from such research. The Alouette and ISIS spacecraft carried, as their central scientific payload, an ionospheric topside sounder among other instruments dedicated to upper atmospheric studies.

Canadian space science also made extensive use of baloons and rockets. The successful Black Brant rocket series, originated by the Defence Research Board and developed by Bristol Aerospace, became an integral part of the Canadian program. Administered by NRC's Canada Centre for Space Science (CCSS), it provided budding scientists and engineers with an ideal opportunity to conduct important research, and at the same time gain valuable training and experience. The balloon and rocket programs were cancelled as an economy measure in 1984.
International cooperation has been a hallmark of Canadian space science, not only with the US, but also with European partners

- particularly the UK, France and Germany, and most recently Sweden. Indeed, Canada enjoys an international reputation for scientific excellence, and has been provided with opportunities to participate in international space science. Present levels of expenditure or space science has been $87.3 Million over the past 5 years, amounting to 13% of total space program expenditures.* The present program, administered by CCSS, involves scientists from academic and government laboratories, and employs Canadian industry in defining and constructing the experiments.

Based on their scientific merit, two Canadian-designed instruments, the Wide-Angle Michelson Doppler Imaging Interferometer (WAMDII) and the Wind Imaging Interferometer (WINDII), and one instrument subsystem, the Waves in Space Plasma (WISP) experiment, were selected by NASA to fly in US sponsored space missions in the late 1980s. In another program, a Canadian firm has completed development and testing of an ultraviolet imager to be launched aboard Sweden's first space research satellite, Viking, in late 1985.

WAMDII measures wind velocity and temperature variations at 80 to 300 km. altitudes using the doppler shift from atomic airglow as measured by a Michelson-type interferometer. It will fly on the Shuttle along with Spacelabe in a mission dedicated to upper atmosphere observations. Conceived by Dr. G.G. Shepherd at York University's Centre for Research in the Experimental Space Sciences (CRESS), the instrument is being developed by SED Systems, Saskatoon.

WINDII, which is similar in principle to WAMDII, will fly on NASA's Upper Atmosphere Research Satellite (UARS) in 1989. One of 11 experiments, WINDII will measure physical and chemical

*Interm Space Plan (1985/86), MOSST News Release, Mar. 20, 1985 processes active in the region 10 to 100 km., including the stability of the ozone layer. France will cooperate with Canada on WINDII which is in the advanced study phase by Canadian industry.

WISP will inject radio waves into the ionosphere using antennas mounted on Shuttle. The reflected energy will be detected by a pair of radio receivers, one aboard Shuttle, and a second on a free-flying satellite that forms a major part of WISP. In this way, ionospheric soundings can be taken - a technique not new to Canada. WISP will take soundings at different sections through the ionosphere and under the direct control of an astronaut. Dr. Gordon Jones of DOC is the principal investigator; however, NRC is responsible for the instrument which is being developed under contract by Canadian Astronautics Ltd. (CAL). CAL is developing the Shuttle-borne high frequency transmitter and a "quick look" receiving facility on the ground to analyze and store the data.

The Viking Ultraviolet Imager, also developed by CAL, will record images of the aurora borealis over the polar cap. Imaging in ultraviolet permits observation of daytime aurora on the sunlit side of the earth. It will provide data on the spectrum, spatial distribution and energy of auroral particles. Principal investigator is Dr. Cliff Anger of the University of Calgary. NRC, the US and Sweden are cooperating on this experiment.

The above upper atmosphere space science programs typify the level and high quality to be expected from the Canadian scientific community over the years to come. Added to the upper atmospheric focus in future will be whatever research programs Canada mounts with respect to microgravity, and the life science research activites associated with the Canadian astronaut program. The latter two opportunities have been opened up by the Shuttle, and the subsequent availability of long exposures to a microgravity environment. These opportunities will be dealt with in later sections.

Should microgravity become an important element of the future Canadian program, then it would be appropriate to re-examine the decision to terminate the rocket program. Rockets can provide up to several minutes of free-fall (microgravity) conditions that have proven to be a valuable research tool and precursor to a flight in Shuttle or Space Station. If materials processing in space holds up its promise, the availability of a rocket facility would become a significant Canadian asset - part of the R and D infrastructure needed by a nation about to enter this high-return market.

In summary, it appears that Canada has a sovereign obligation to conduct research on the ionosphere and upper atmosphere in the auroral zone surrounding the north magnetic pole. The international partnerships Canada has developed, particularly with the US, has provided Canadian scientists with opportunities otherwise denied by the prohibitive costs of space research. Space science provides an excellent training ground for scientists and engineers. Thus such research activities should be perpetuated and expanded in proportion to the growth of the Canadian space program as a whole.

Finally, by the end of the century, further exciting opportunities will be opening up for Canadian scientists, should the concepts now being developed by the US National Commission on Space be implemented. It should be part of a Canadian space strategy to study the participation of Canadian scientists/astronauts in the initial manned exploration of the inner solar system, and in the construction of future space stations in earth-moon and earth-Mars orbits, including the provision of space science payloads.

4.5 Space Station

In 1982, NRC undertook, as part of its Space Technology Program, to study the benefits to be derived from Canada`s participation in the development and use of Space Station. Completed in 1985, the NRC study was part of the Phase A preliminary investigations to define national areas of interest in which the US, Canada, ESA, France, W. Germany, Italy and Japan participated. The studies included an appraisal of the possibilities for each nation to participate in the program, an assessment of the contributions according to their existing technology base, and an estimate of their potential use of the facility.

The Canadian Phase A studies included:

- survey of potential Canadian users of the Space Station infrastructure and their requirements
- assessment of sub-systems from the Canadian technology base that could form a basis for participation
- investigation of Canadian needs in space biology
- assessment of the economic potential of Canadian participation
- participation in the health maintenance facility of Space Station
- a study of Canadian MPS interests

The conclusions from the studies were that Canada has a strong, established technology base that could contribute towards a Space Station infrastructure, and make good use of it. Canada's role in Space Station would be that of a supplier of specialized equipment, systems and structures; and of a user for scientific and technical research, for remote sensing and for commercial purposes.

In March, 1985, the Ministry of State for Science and Technology announced, as part of the Interim Space Plan, that Canada would accept the US invitation to join the Space Station program.

Definition and design activities, Phase B, will be divided into Phase B1 (to Mar. 1986) and Phase B2 (Apr. 1986 to Mar. 1987). Canadian Phase B studies are expected to include four work packages:

1. Space construction and servicing systems (SCSS)
   - integrated servicing and test facility
   - robotic servicer
2. Solar arrays for space platforms (up to 25 KW.)
3. Remote sensing facility on a polar platform
4. User development program and economic benefits analyses

The Phase A assessment of sub-systems which could form the basis for Canadian participation built on technical areas in which Canada has already established a technology base. These areas centred on the enormously successful Shuttle Remote Manipulator System (RMS), Canadarm, developed by NRC and Spar Aerospace alongside a strong subcontractor team. This technology is ideally suited for Space Station applications.

The Spar Phase A efforts were directed to the requirements for the Space Construction and Servicing System (SCSS). Space construction and servicing activities will be performed principally on:

- the Space Station and its payloads
- co-orbiting and polar platforms and their payloads
- free-flying spacecraft

Such activities will be located on various elements of the infrastructure: STS orbiter, Space Station, OMV and OTV.

The manned Space Station will be the main location for construction and servicing and thus will have the maximum of capabilities. The Spar design studies have focussed on an Integrated Servicing and Test Facility (ISTF) at this main location. The ISTF centralizes some of the servicing functions on the station:

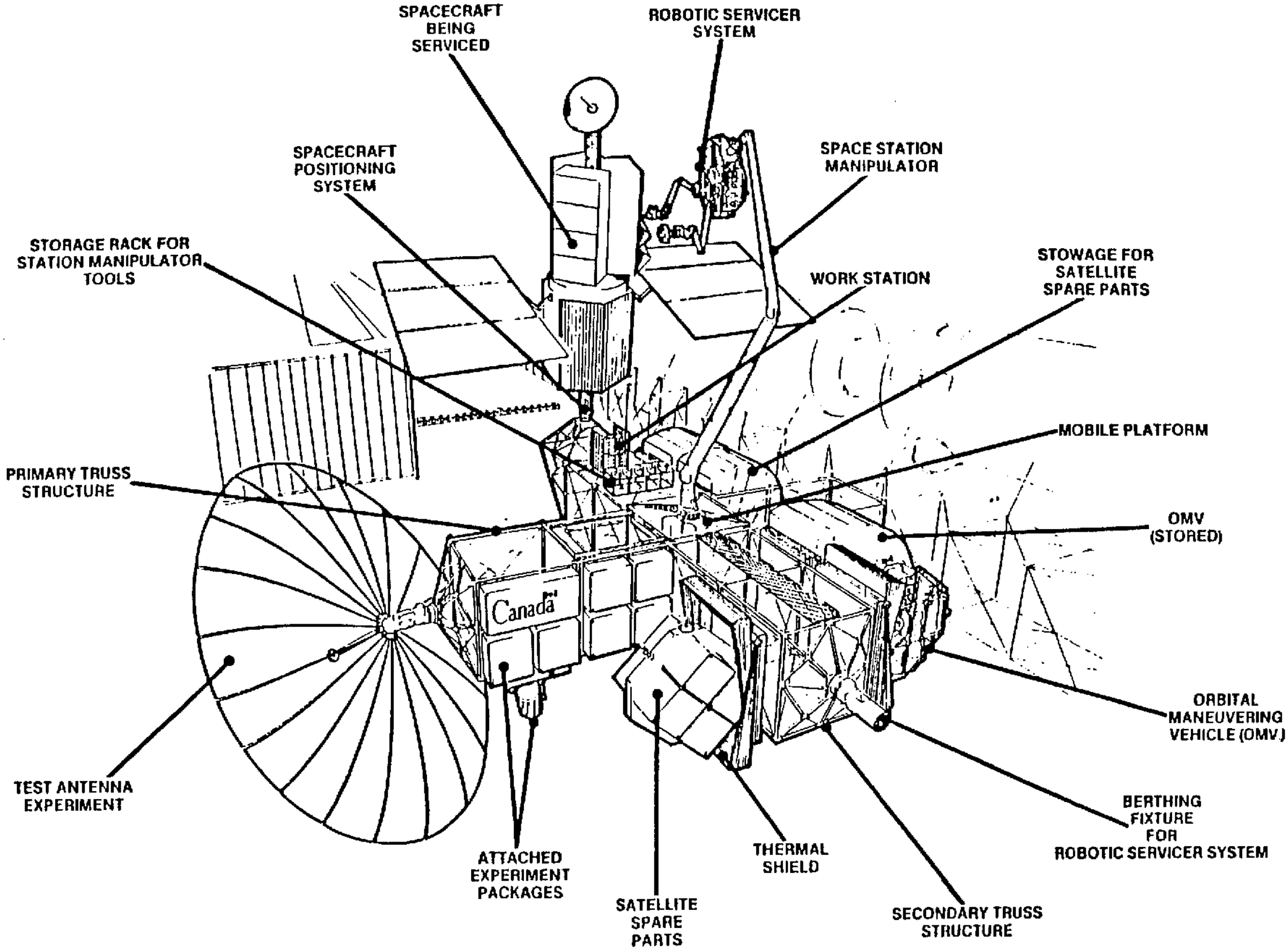
- Payload servicing
- OMV servicing
- OMV storage
- Proximity operation with OMV
- Orbit Replacement Unit Storage (OMV and payload)
- Tools
- EVA work station
- Large structures construction and testing
- Structure and mechanical support for servicing
- Fuel tank exchange
- Support for refuelling at refuelling facility

The ISTF manipulator would support initial construction of the Space Station, controlled from the orbiter aft crew station.

One possible configuration of the ISTF appears in Figure 4.1.
It consists of:

a) Space Station Manipulator System
   - supports initial space station construction
   - supports servicing activities on board station
   - will be controllable from IVA and EVA work station's
   - may be controlled from the orbiter aft crew station

b) Robotic Service System
   - performs tasks requiring dextrous activies
   - may be controlled in either teleoperator or robotic mode



INTEGRATED SERVICING & TEST FACILITY (ISTF)

Figure 4.1

c) Facility Accommodations System
- integrated facility based on Space Station structure
- spacecraft servicing and assembly accommodations
- servicing tools
- work station
- provisions for unpressurized test bed
- large space structure construction accommodations
- attached payload accommodations

d) Facility Control Station
- provides overall control of ISTF
- installed in pressurized environment
- includes provisions for external control by EVA astronauts
- supports spacecraft, OMV servicing, checkout, deployment and retrieval

The Phase B1 contract was placed on Aug. 1, 1985, and will study in more detail the the robotic servicer system, a Space Station RMS, the facility systems, a simulator and a management system.

The AD 2000 scenario suggests at least one fully-developed in-orbit infrastructure (NASA), possibly a second (ESA) and most likely a third (USSR). The technology required for the ISTF would provide an opportunity to offer a commercial service. Should the development of free-flyer and man-tended materials processing facilities materialize, a need for on-orbit services arises. The Center for Space Policy estimates a $296 Million high scenario for the year 2000, based on the emergence of a commerial MPS activity which would need to purchase such services.

Canadian long-term interests in remote sensing and meteorological satellites are well-served by ISTF technology. Future spacecraft such as Radarsat and beyond will be designed for in-orbit servicing, a feature that has added $500 Million to that satellite's net present value, since its life will be extended from 5 to 10 years. Similar kinds of benefits will be realized from OTV-serviced communication satellites. The fact that such spacecraft will be serviced using Canadian technology adds to their value as an expression of Canadian sovereignty, independence and technological strength.

4.6 Materials Processing in Space (MPS)

Canada's role in Space Station will be not only as a supplier of specialized equipment, but also a user. One of the major use categories as described in Section 3.8 will be materials processing, which makes use of the microgravity environment. This area could take on properties of becoming a separate industry, if the potential returns now being imputed hold their promise. Accordingly, MPS studies were included in the Space Station Phase A studies.

The MPS studies took the form of Industrial Joint Endeavour contracts. Six such contracts were let in which specific application areas were examined as to their commercial potential: semi conductors, crystal growth, pharmaceuticals and biological products, metals, ceramics and glasses. The results of these early studies, in which the proprietary rights of each participant were recognized, uncovered five areas of specific interest to Canadians users:

1. Gallium Arsenide - three techniques for manufacture
2. Ceramics and bubble-free glasses
3. Pharmaceuticals - beta cells
4. Fermentation techniques to re-cycle food
5. Metals-dispersed phase stability of polymers and the joining of metals (aluminum) in space

Four of the contractors developed proposals in these areas which were deemed to be ready for space experiment in the 1988 time frame. The remaining two wished to conduct more earth-based research before pushing off into space. NRC estimates that from 1988 onward, Canada will be ready to fly the equivalent of six GetAway Special Cannisters (GAS-Cans) per year dedicated to MPS.

With specific Canadian MPS missions now identified, the issues turn to the costs and availability of carrier space on the orbiter. There are a number of options, but they are all impacted by NASA's recent price hike where the cost of occupying space in the Shuttle bay has almost doubled. Recognizing it is NASA's intention to move toward total cost recovery, prices may rise to where the economics of MPS are no longer attractive for some processes.

There are three shuttle carriers now in use:

1. GAS-Cans - least expensive carrier (20" x 28" cylinder), must be autonomous (no external power); payload of opportunity with no priority - some experiments have been waiting up to 3 years
2. Hitchiker - higher volume and weight capacity than GAS-Cans, a payload of opportunity
3. Spartan - differs from above in that it is a primary payload considered in mission planning, can be deployed for 40 hours, then retrieved by Shuttle
4. Spartan Probe - a proposed free-flyer deployable from Shuttle that can eject a carrier 36" in diameter, 30"-40" in length with a maximum weight of 350 lbs.
5. SPAS - MBB/Erno Shuttle Pallet Satellite (SPAS) already launched twice from Shuttle, is ESA's free-flyer; MBB would rent or sell platforms

There are two Canadian carrier proposals - Bristol Aerospace's Flexible Orbit Carrier Using Shuttle (FOCUS) which is a free-flyer like Spartan, but with a propulsion system, and NRC's Canadian Space Carrier (CSC)*. The CSC is a bridge-like structure that would mount into and span across the Shuttle cargo bay to support instrumentation and equipment. It could accommodate a payload volume of 5m x 4m x 1m with a weight of up to 1500 kg. It could be deployed and retrieved for free flights up to several days with its own attitude stabilization, power and control functions. The design provides for one flight per year for ten years. Development costs are estimated to be $3-5 Million, and the cost of one Shuttle flight is in the order of $9 Million at today's prices.

The principal argument for CSC is that Canada will need its own free flyer, not a payload of opportunity which can readily be pre-empted by other payloads of higher NASA priority. The main advantage of a free-flyer is the quality of microgravity environment attainable. On Shuttle, crew movements and attitude adjustments create residual gravity in the order of 10^{-3} to 10^{-1} g's, which may be too high for some sensitive processes.

Various CSC funding levels and arrangements are being studied. The expectation is that industry will share in the costs of the CSC, and that the program will be operational by the 1988 time frame. In the context of the world scenario developed in Sections 3.7 and 3.8, the IOI and MPS activities will gain momentum slowly through the 1980s, but then accelerate rapidly through the 1990s with the advent of Space Station and Columbus. If Canada is to have a place in that future, then it must lay the necessary ground work now and plan its expenditures accordingly. As with all forms of new technology, MPS will need to be fostered by government until industry gains a much clearer picture of the risk/reward ratio and makes the inevitable investment.

*Proposal for an Independent Canadian Shuttle Based Carrier, prepared for NRC by B.V. Tryggvason, M. Garneau and S.G. MacLean Canadian Astronaut Program Office, June 10, 1985.

4.7 National Defence

The general military situation between the US and the USSR briefly described in Chapter 3 in the form of an air-launched missile threat combined with general advancement in military communications technology and the move toward a US Unified Space Command has had significance for the Canadian Defence Program.

Currently DND is considering expanding its use of space capabilities, specifically in the areas of surveillance and communications. In 1983/84 DND forwarded an analysis of defence requirements in space to the Interdepartmental Committee in Space (ICS) indentifying its requirements as follows:

- Surveillance of the Arctic and East/West Coasts as a military operational capability;
- Communications in the sense of a support or service capability rather than in the command, control and communications (C^3) context;
- Navigation as an operational capability element;
- Search and Rescue (SARSAT).

It is noted that the movement of DND into greater usage of space based systems in the pursuit of higher levels of military operational effectiveness poses some problems for the Department since this adds a fourth dimension to the Defence Program (additional to the Land, Sea and Air environments) which has to operate within the constraints of a fixed budget. Consequently, it is not envisaged that DND would be planning to mount its own space systems, with completely native Canadian satellites for Canada's security needs.

The renewal of the joint NORAD agreement and the announcement of the North Warning System has acted to stimulate emphasis on space systems utilization in DND. This stimulus centers on the point that, whereas the main Canadian contribution to NORAD has traditionally been in the areas of ground-based surveillance, the new North Warning System is to be centred upon space--based surveillance. Consequently a significant change in the Candian role is required in harmony with the joint agreement. This new initiative is embedded in the DND Research and Development Program and has taken the form of a major R&D program (planned at the level of $50 Million over 5 years) in Space-Based Radar. A high proportion of this work would be conducted in Canadian Industry. The application of the technology development then could be employed by Canadian Industry in supplying the North Warning System.

A further major space program thrust in DND is a joint program with US DOD in the EHF SATCOM project within the US DSCS (post DSCS III) program. This technology development activity is relevant to high data rate EHF Military Satellite communications sytems. DND funding in this program approximates the same level as the Space--Based Surveillance Program. Again the major portion of the work is contracted out to Canadian industry over the next five years.

These two programs combined with lesser programs, leading to trials in the 1990 timeframe, are expected to contribute in a major way to the development of the Defence Technology Base in Canada. They will also help to develop Canadian industrial capability in the space communications and surveillance applications. The potential spin-off of this military system involvement into other areas of the Canadian Space Program is by no means insignificant, and could be substantially greater if some means could be found for a greater cross-integration between military and civilian programs.

4.8 Technology

4.8.1 Introduction

The viability of the Canadian space program in large measure depends on the level of technology that the industry is capable of sustaining. Recognition of this principle by the government has given rise to a number of technology support programs, some associated directly with the space program as such, others are of a more general nature available to industry at large. As well, multi-departmental memoranda of understandings, (MOU's) are being developed wherein major companies negotiate an agreement in principle to share R and D costs with government in a wide area of technologies over an extended period of time. Such MOUs are administered through DRIE.

Since technology can be singled out as a separate program and funding activity, the following paragraphs examine those areas of technology that are keys to Canada's space program, and which may need to be funded separately as part of the "price of admission" or "overhead" for entry into the world space market.

The process of identifying key technologies was to examine the principal ingredients of each program area and list the key elements. Specific technologies then could be identified for each of these key elements; however, not all such technologies are necessarily critical or strategic. The next step was to select those technologies that are likely to be critical in future; the AD 2000 scenario was chosen for this purpose. A listing was made of the Year 2000 strategic technologies for each of the key elements. From this list, it was possible to identify the key technologies that need to be fostered in order to ensure the continued and enhanced growth of a Canadian industrial space capability.

The results of the process are displayed in Tables 4.1 and 4.2. Each program area within the overall program framework has associated with it a number of separate parts peculiar to the mission, which could be at the system, sub-system, unit or even component level. For the purpose of convenience, they have been termed key elements, and are listed in Table 4.1. In general, the key elements are technology-dependent critical links in the mission process. They help to focus on those technologies that are strategically important to the success of the program area.

Table 4.2 extrapolates to the Year 2000, listing those technologies that will be of strategic importance against the specific key elements identified in Table 4.1. The sources of data for Table 4.2 consisted mainly of individual experts in government and industry with senior responsiblities and long-term experience in the Canadian space program. It also drew from the reference material cited in earlier sections of this report.

4.8.2 Key Technologies

Table 4.2 lists over 60 technologies that are considered to be strategic to the Canadian space program by the Year 2000. Since they appear opposite each of the key elements, there are some repeats and redundancies. Some technologies such as artificial intelligence and robotics are common to several elements.

The following headings, derived from Table 4.2, are an attempt to aggregate certain of the strategic technologies into key technological areas that need to be stressed in the Canadian program. They represent areas that should be the subject of special attention, because they relate to the core capability of the Canadian space industry. No priority is intended by the order in which they appear.

TABLE 4.1 (p. 1 of 2)
KEY ELEMENTS

Program Area	Key Elements
1. Communications (DOC/CRC, Telesat Canada)	• Antennas and feeds • LNAs • MUXs and filters • HPAs solid state • Signal processors/switches • Systems • Spacecraft bus: - structures - rigid and flexible - solar array - power conditioner and systems - thermal systems - attitude control
2. Remote Sensing (EMR/CCRS)	• Microwave sensors - active - passive • Optical/Infrared sensors - spatial and spectral arrays • Pointing systems • Data processing, storage & retrieval • On board image analysis, pattern recognition • Data basing • Spacecraft bus (as above)
3. Space Science (NRC/CCSS, NSERC)	• Specific to each payload and space science mission • Elements of specific Canadian mission • Elements of specific Canadian missions include WAMDI, WISP, etc. • astronomy
4. National Defence (DND-CRAD/DREs, CADO/SASS	• Space-based radar • Communications systems • Navigation/positioning systems

TABLE 4.2 (p. 3 of 3)

STRATEGIC TECHNOLOGIES - YEAR 2000

Data Basing	• Data base topologies • Relational systems
Space Science	• Cryogenic systems • Robotics • Special sensors, spectrometers • Data acquisition, on-board processing
National Defence	(Strategic technologies from CRAD documentation) - surveillance - communications (e.g. Molnya orbits) - navigation/positioning
Telerobotics/telepresence	• AI, expert systems • Sensor Systems • Image Analysis, pattern recognition • High torque/weight actuators • Light-weight structures and materials
Integrated Servicing & Testing Facility	• Robotics, teleoperator systems and end effectors • Torqueless tools • Cryogenic fuel transfer • Space construction
Materials Processing	• Furnaces • Containment systems • Biomaterial handling • Separation technologies
Mechanisms	• Mechanical device technology • High strength-to-weight ratio materials
Large Space Structures	• Advanced materials • Unfurling techniques • Passive and active thermal control

1. Microwave Technology - includes antennas and feeds, solid state power amplifiers, low noise amplifiers, electronically-scanned phased arrays for communications and radar applications

2. Microelectronics - covers a wide range of sub-systems in space and other applications; includes very large scale integration; microwave integrated circuits -hybrid, thin film and monolithic; gallium arsenide technology

3. Artificial Intelligence - on-board decision making, fault isolation, diagnostics and self-repair, plan generation; image analysis and pattern recognition; robotic control

4. Radar Systems - synthetic aperture radar, beam steering and switching; on-board signal processing; multi-polarization, frequency agility

5. Optical Systems - array detectors, narrow band imagery, focal plane signal processing, communications lasers, cryogenic coolers

6. Robotics - high dexterity robots, autonomous robotics, robotic control theory, sensory feedback, man interfaces

7. Advanced Materials - advanced composites (e.g. metal matrix) for high strength, high temperature use; ceramics; composites for microwave use

8. Large,Flexible Structures - solar arrays; antennas; space structures; thermal design; attitude control; pointing

9. Energy Conversion/ Power Conditioning - gallium arsenide cells, concentrators, energy management, autonomous control and self repair

10. Data Management and Processing - high speed, on-board processing; high speed, high volume ground data processing, data basing; high-order universal language, automated software generation

The AD 2000 technologies will include new capabilities such as in-orbit servicing, refurbishment and repair, and on-board autonomous problem-solving and operations planning. The spacecraft effort, and will play an increasingly important role as Canada takes its place in Space Station as a supplier and user of in-orbit facilities.

In the following paragraphs, two of the major support programs that are critical to the success of current and future space activites are singled out for examination. They are the David Florida Laboratory and the Canadian Astronaut Program.

4.9.2 The David Florida Laboratory Program

The David Florida Laboratory (DFL) program at DOC's Communication Research Centre is a national facility for the assembly, integration, environmental and ambient testing of space components and complete spacecraft. The support is made available on a cost recovery basis. The program was originally designed to satisfy the subsystem environment testing needs of the Communications Technology Satellite (HERMES) program. The program's original client base has been extended to include the environmental testing needs of the Canadian aerospace industry as a whole, with particular emphasis on the needs of the designated prime contractor for the Canadian space program - Spar Aerospace Ltd. The number of companies taking advantage of DFL's services has grown to over thirty companies and agencies which bring over 75 projects to the DFL annually.

The facilities currently include provisions for vibration, thermal vacuum, radio frequency testing, mass properties measurement, and for spacecraft integration at the component, system and spacecraft levels. As part of the development of the spacecraft prime contractor capability in Canada, a $120 Million extension of the DFL facilities was built so that entire Shuttle-class spacecraft could be accommodated.

The extension was completed and certified, and supported the Anik C-2 and Anik D-1 and D-2 spacecraft programs, and the SRMS follow-on procurement. DFL facilities are being used by Brasilsat and ESA-sponsored L-Sat (Olympus) programs. A further addition of integration and support facility areas and test equipment is becoming necessary, and will be implemented during the construction of additonal high-bay space (Bay 3).

In addition, the DFL is committed to provide testing services to much of the Canadian aerospace and communications industry, and to government departments on a range of domestic and international programs which include Skynet 4, Viking, RCA Satcom and Intelsat VI. Technical consultation is also provided by DFL staff in support of programs such as MSat and Radarsat, and other research activities at CRC.

DLF is a national facility that rounds out Canada`s capability and credibility as a prime contractor and major supplier in the world space milieu. However like all other government services, DFL is expected to recover its costs from users. DFL costs are thus built into the price structures of its clientele. A problem could develop if DFL's price schedules get altered in such away that industrial clients have insufficient time to enter them into their own quotations to customers. In addition, it is possible that DFL could price some Canadian space suppliers right out of the marketplace. Thus the rate of cost recovery and pricing strategies could be issues that become critical in future as the Canadian space industry faces increasingly severe competition in an impending buyer's market.

4.9.3 The Canadian Astronaut Program

The Canadian Astronaut Program began with an invitiation from

NASA in 1982 for Canada to establish its own astronaut program. This came as a direct result of the Canadarm program, and was formally accepted in 1983. Two flights were identified and 6 astronauts were selected in December 1983 from 4300 applicants. The objectives of the program are:

1. To undertake two Canadian experiments in space with the Shuttle:
   - space vision system (space technology)
   - space adaptation syndrome (life sciences)
2. To undertake other experiments in space involving Canadian Astronauts
3. To increase the general public's awareness of the Canadian space program and its benefits
4. To encourage young Canadians to pursue careers in science and technology

The first flight occurred as the result of an unexpected invitation in early 1984. Comm. M. Garneau flew in October, 1984 on NASA's Mission 41G as a Canadian payload specialist. He conducted experiments for 5 teams of Canadian investigators in life sciences, space sciences and space technology.

Present activities include the necessary follow-up to Mission 41G, preparations for the next two flights, support of Space Station and Radarsat study activites, participation in NASA life sciences project (Space lab), investigations into the Canadian Space Carrier requirements, payload specialist training and public appearances.

Future activities will include flights in 1986 and 1987 where the selection of prime and backup payload specialists is made approximately one year in advance, and training moves to the Johnson Spaceflight Centre 4 months before launch. In the longer term, it is intended to expand objectives to include the provision of mission specialists in addition to payload specialists, and place two Canadians into the pool of NASA mission specialists. Then it will be necessary to increase the size of the Canadian astronaut corps from 6 to 8. In this way, Canada can prepare for its Space Station role as a supplier (relates to the mission specialist) and as a user (relates to the payload specialist).

The rationale for adding mission specialists is its congruency of purpose with the ISTF contribution, which is part of the basic Space Station and not associated with any particular payload. In this circumstance, the astronaut forms an important feedback link to the design team developing the facility.

The advantage of having a dedicated payload specialist on board is the length of time he or she can devote to Canadian experiments. Comm. Garneau was able to devote 10 hours per day to Canadian payload specialists' experiments during Mision 41G.

The principal issue surrounding the Canadian Astronaut Program is the flight and training charges imposed by NASA. These charges amount to $1.3 Million for two flights per year. Yet for the reasons given, there appears to be no reasonable option but to pay them if manned intervention on board is essential. Otherwise Canada would have to use proxy-investigators, or design all future payloads to be totally automatic and autonomous.

CHAPTER 5
A.D. 2000 SPACE MARKET

5.1 Introduction

Chapter 3 has described in some detail, in the program and technological context the probable evolution of the space environment over the next 15 years to A.D. 2000 in terms of space systems and space applications with some reference to the space plans of other countries.

Chapter 4 has commented in detail upon the implication for communciations, remote-sensing, space science activities in the Canadian context as seen to be relevant to consideration of any future Canadian Space Policy. Particular attention has been given to Space, Station, materials processing and support programs. A list of key technologies and technology areas has been formulated unconstrained by current Canadian technology base limitations.

As a consequence of the foregoing a number of issues emerge in the context of present elements of the Canadian Space Program which must be considered as critical factors in formulating a future Canadian Space Program:

- competition between fibre optics and fixed satellite services in the communications market;
- levels of Canadian content in the ANIK program;
- maintenance of Canadian prime contractor capability;
- public vs. private financing of MSAT;

- market viability of the Canadian earth segment industry;
- relevance of Canadian earth observation satellites in Canadian sovereignty and particular Canadian needs;
- Canadian participation in international space science initiatives; traditional Canadian areas of space science focus and new areas (commercial microgravity; manufacturing);
- space platform utilization;
- Canadian space program infrastructure and support elements.

In this chapter we make some reference to the technological policies reflected in other nation's space plans that have been reviewed and comment briefly upon some global trends with reference to particular nations. In the global context the crucial space technology issues in terms of communications, remote sensing, and space science are postulated.

This is followed by an organization of the A.D. 2000 marketplace into Buyers and Sellers and the dynamics of the marketplace from 1985 - 2000. Some analysis of market character and behaviour which impacts upon Canadian opportunities is undertaken and the chapter concludes with a discussion of Canadian Government and Industry Structural factors which affect future Canadian Space Policy.

5.2 Overview of Other Nations' Space Policies and Trends in Technology

In this context, technology is to be understood as the successful synthesis of an aggregate of specific skills, techniques and components, however complex, to accomplish a social or economic objective. By this definition, research and development are not technology: they are the means by which new technology is proven out, becomes established, and gains acceptance. Space technology is an intermediate accomplishment, a form of investment, the full benefits of which come with the successful use of it, or spin-off from it, to achieve a program goal.

5.2.1 Policies

The policies of countries and international agencies with respect to space technology are reflected in their policies regarding applications programs. These policies have been examined in the previous chapters and will not be repeated here.

Exceptions are policies regarding the technology of space station and SDI in the U.S.A., and ESA's version of a space station, the In Orbit Infrastructure, or IOI technology. These technologies are so complex and expensive that inauguration of a program of R&D to put them in place requires executive decision at a high political level. Furthermore, a policy to proceed with one of these major technology program sets a policy, de facto, to proceed with R&D on many subordinate technologies.

The U.S. has taken a decision to proceed with space station technology with a view to launching a space station in the 1990's. The application programs to be supported by this first space staion in the westen world are yet to be decided but it is certain that there will be a large number and variety of them. The technology to process materials in microgravity environment has already gained wide interest because of encouraging research results thus far.

The U.S. has also taken a decision to proceed with research on SDI. Like space station, the surveillance and communications elements of SDI technology will require new levels of technology in topics such as optics, image processing, radar, computing and adaptive communications systems.

ESA has done extensive analysis of options for IOI with or without the U.S., manned and unmanned. A long-term policy decision is still to be taken. An interim policy to cooperate with the U.S. is being implemented.

The U.S.S.R. has been operating manned space platforms for several years. Plans for future technology thrusts into systems like space staion must be presumed, whether or not they have been publicly articulated.

Broadly speaking the policy of Western countries towards space technology is to seek advancement in those areas where the use of new space technology will yield economic or social benefits to national programs and goals.

5.2.2 Space Technology: Global Trends

To some degree or other most countries active in space have domestic R & D programs aimed at solving the barriers to new space technology.

The U.S. and the U.S.S.R. carry out significant R and D in the entire field of space technology and thereby maintain an independent national capability. ESA, Japan, France and Germany follow, with very extensive space technology programs, including an indigenous launch capability in France (with ESA backing) and Japan. Of the U.S., U.S.S.R, ESA and Japan, it can fairly be said that of whatever is new in space technology, these countries and agencies are working on it. Conversely, by observing the emphasis put onto new technology by these major players or space technology drivers, one can infer the trend of development in space technology, at least as it concerns technologies requiring substantial funding.

Table 5.1 illustrates a number of future space technologies which are under active development around the globe and deemed essential to support new technology in application areas. The application areas examined in the three previous chapters have been used for the table. Other areas such as defence, embrace virtually all application areas; still others such as navigation serve a narrower constituency, albeit a potentially attractive one from the point of view of sales of terrestrial equipment.

TABLE 5.1

FUTURE TECHNOLOGIES REQUIRED FOR NEW GENERATIONS OF APPLICATIONS

CRITICAL SPACE TECHNOLOGY	COMMUNICATIONS	REMOTE SENSING	SCIENCE
Space Station	Advantageous but not critical	Key to high resolution multi-band spectroscopy	Key to commercial microgravity manufacturing
On Board Signal Processing	Critical to new generation of switchboard-in-the-sky satellites	Critical to simultaneous use of hundreds of sensor channels and on-board image analysis	Advantageous but not critical
In-orbit Servicing	Advantageous for cost-effectiveness	Critical to space-tended operation of free flyers	Critical to space-tended operation of free flyers
Distributed-aperture antennas with adaptive beam control	Critical to large integrated-service communications satellites	Critical to staring radars	Advantageous
Fault-tolerant computers	Advantageous to on-board switching	Key to on-board image processors Key to on-board SAR processors	Advantageous
Distributed control of large loosely coupled mechanical systems, mechanisms for space	Critical to large integrated-services communications satellites	Critical to staring radars Critical to large integrated-services satellites	Critical to large integrated-services satellites
Precision pointing and tracking	Critical to large integrated-services communications satellites	Critical to staring radars Critical for sensors with high spatial resolution	Critical for astronomy
Secondary power battery management	Key to long-life Key to day/night operation	Key to long-life Key to day/night operation	Key to long-life Key to day/night operation
Primary Power - 10-100kw range - high reliability - high power/weight ratio - non-hazardous	Key to integrated-services satellites	Key to integrated-services satellites	Key to integrated-services satellites
Re-usable, safe propulsion systems	Advantageous	Key to space-tended free flyers	Key to space-tended free flyers
Robotics with some AI	Not critical	Critical to unattended self-management of platforms	Critical to unattended self-management of platforms
Space Construction	Critical to huge multi-service satellites	Critical to huge multi-service satellites	Critical to huge multi-service satellites
Other	High reliability, complex transponders	Multi-band high spatial/ spectral resolution images	Microgravity process technology

Space station has been included in Table 5.1 as a technology rather than an application program because a space station is not an end in itself, however an impressive a technological breakthrough it might be. As noted earlier, space station requires virtually all elements of current and future space technologies to support the variety of activities associated with managing and using a space station to deliver applications programs.

AUSTRALIA

Australia will develop new space technology by contributing to other countries' missions. Australia may join ESA to acquire technology for commercial applications of space.

GERMANY

Preparatory research on technologies to improve the feasibility of future applications projects will be carried out, but emphasis is on applications technology.

Industries will be supported to develop the technology of space transport facilities.

FRG will develop and test reusable, free-flying STS-launched space platforms. The FRG national test facilities and ground control installations are to be integrated and rationalized into a joint European system.

The Spacelab technology is to be upgraded. Research to develop robotics, cryogenic motors, space structures and new in-orbit propulsion is to be carried out.

JAPAN

Japan will develop a manned space technology if research activity warrants it. Technology of satellite clustering and automatic satellite assembly is planned. Improvements to the technology of on-board power sources, computing and satellite control will be researched. New technologies for orbital manoeuvering, satellite recovery, and rendezvous/docking will be developed. As already mentioned Japan will maintain an independent launch capability for modestly-sized payloads.

ESA

Some highlights of the ESA future technology program are the ARIANE 5 launcher; upgrades to the ESA launch complex in South America; with NASA (to 1995), improvements to European manned capabilities in Low Earth Orbit (LEO); refinements to the in-orbit infrastructure to support science and applications and preparations for an autonomous European infrastructure to support man in LEO.

U.K.

The trend of technology in U.K. is to continuing development of the Olympus bus as a multipurpose applications support platform and to seek cost-effective or commercial application of remote sensing from space.

FRANCE

The trend of space technology in France for the forseeable future will be such as to maintain the French position, globally, in communications, direct broadcasting and earth observation. Following successful completion of the Ariane launcher development, Telecom I, TDF1 (DBS), and SPOT satellites programs, France will exert greater efforts in the areas of competitiveness and marketing to increase international market share for French products.

The breadth of the French space technology program, encompassing as many applications as it does - space science, man-in-space, remote sensing, search and rescue - and the desire to remain as a world-class performer implies that France will seek improvements to most of the technologies given in Table 1. Through CNES the Centre Nationale d'Etudes Spatiale France has a well-focussed space technology and applications technology program.

U.S.

Manned space station is the center piece of the U.S. technology trend for the next 15 years. To achieve this goal in the most cost-effective manner will require continuing effort on several subordinate technologies:

(i) a Life Sciences program to ensure the health and well-being of spaceflight crews will be developed. Among the problems to be solved are space sickness, cardiovascular changes, and dysborism (bends). Controlled ecological life support technology is to be improved.

(ii) Research to determine the optimum distribution of tasks between man and machine in space is to be continued.

(iii) Advanced studies of data volume requirements in the 1990's will quantify the need for more satellite relay links and greater capacity in the TDRSS follow-on era.

(iv) Disciplinary research subjects such as fluid and thermal physics; space energy conversion; chemical propulsion; controls and human factors; large antennas; space teleoperation, robotics, and autonomous systems indicate some specific technology trends for the next decade.

5.2.3 The A.D. 2000 Technology Scenario

The major focus of space technology in a 2000 A.D. scenario is the first generation of manned space stations supporting unmanned multi-purpose platforms and dedicated free-flyers. The current U.S. (NASA) concept for early 1900's is a manned element at 28.5^{o} orbital inclination, a platform at low inclination and a platform in polar orbit. The technology to permanently inhabit space will be the most significant accomplishment by 2000 AD first, because it represents the successful synthesis of so many subordinate technologies and second, because it will usher in a new level of maturity in applications such as remote sensing, scientific exploration of the universe, industrial microgravity processes and defence to name four.

The subordinate technologies required to establish a first-generation space station are essentially those set out below. Many of these technologies have been identified or implied also in Chapters 3 and 4.

Launchers - 2000 A.D. is expected to see a fully operational economically profitable STS in the U.S.A.

Power - Many tens of kilowatts of primary power from safe, reliable sources, coupled with onboard energy storage.

Life Support - Complete life-cycle support systems for permanent manned presence in space.

Man-machine - Advances in artificial intelligence and robotics, coupled with better understanding of man in the space environment for prolonged periods, will see major changes in the technology of man and machine as an integral functioning unit.

Self-Managed Satellites - The advances in AI and robotics noted above, coupled with new technology in fault-tolerant computing, precision pointing, and distributed attitude control of large structures will see the introduction of 'smart' satellites with on-board decision making and intelligent response to users on a space station or on earth.

> Self-Managed Satellites - The advances in AI and robotics noted above, coupled with new technology in fault-tolerant computing, precision pointing, and distributed attitude control of large structures will see the introduction of 'smart' satellites with on-board decision making and intelligent response to users on a space station or on earth.

The new applications technologies described in Chapters 3 and 4 if they are to be in place by 2000 A.D. will imply successful development of the technologies listed above for Space Station. In general terms these are the technologies that, for a particular satellite or space platform, provide for its deployment in space, provide its technical capability, and allow a user to access the satellite's functional capability. In particular, the technology for utilizing the product of a particular satellite or class of satellites to make results available and cost-effective to a wider constituency than the current group of interested experts is expected to be much more mature than at present. The stated objectives of several administrations to 'cash-in' on commercialization of the products of space technology will be a driver in this scenario.

5.3 The A.D. 2000 Marketplace

In order to describe the Marketplace in the A.D. 2000 environment the space product areas have been taken in two parts (and the major elements of these parts) in order to highlight program concentration areas of major suppliers. The nations wich comprise the Space Community in turn have been classified into buyers and sellers (suppliers). The Suppliers are classified as Tier 1 Space Nations and the Buyers as Tier 2. A number of buyer nations are in the process of becoming suppliers. Nations which are not specified are considered to be buyers, at least through the period to A.D. 2000

Consequently space products have been grouped into the following families:

(i) Space Systems and Systems Technology

a. Launch capability and facilities
b. Satellites and Payload
c. Space Platforms
d. Space Transportation Vehicles
e. Ground Segments
f. Space System Infrastructure Management
g. Space System Development

(ii) Space Applications and Applications Technology

a. Communications
b. Remote Sensing
c. Products and Technologies
d. Research

Study of the literature and documentation in terms of the space plans of nations has provided fourteen nations and one international institution which have been classified into Tier 1 and Tier 2 categories based upon their relative status and roles through A.D. 2000. The Tier 1 nations (sometimes referred to as the space pioneers) have significant investment in technology base, and, beyond being suppliers of substance are primary drivers of space initiatives. The Tier 2 nations are generally buyers which however are in the process of developing toward Tier 1 level. Not all are on the same point on the "development curve" but all are eventual potential competitors to the present Tier 1 nations. These national classifications are as follows:

<u>Tier 1 Nations</u>

- Canada
- United States
- ESA
- France
- Germany
- Japan
- U.S.S.R.
- China

<u>Tier 2 Nations</u>

- Australia
- India
- United Kingdom (primarily through ESA)
- Brazil
- Sweden
- Korea
- Indonesia

5.3.1 Tier 1 Nations A.D. 2000 - Comparable Positions

Table 5.2 reflects a broad analysis of the strengths of Tier 1 nations as of today (1985) and in A.D. 2000 (as extrapolated from our research) in the elements of Space Product Structure. The ratings accorded to Canada in A.D. 2000 are notated as "Interim" for obvious reasons. The most dynamic shifts between 1985 and 2000 are in relation to Japan and China. Levels of activity and potential achievement are graded as High, Medium, and Low. Essentially the element "Space Platform" refers to Space Station, and Columbus projects for which the detail of participation and planning are not well defined. Elements for which a nation can be considered to be "prime" are so noted with a "P" in the upper right of the block.

Significant movements from the present to AD 2000 by nation are as follows:

<u>Canada</u> - Low to Medium in Space Systems Development

<u>United States</u> - Medium to High in Ground Segments, High Level in System Infrastructure Management

<u>ESA</u> - Low to High in Ground Segments

<u>Germany</u> - Medium to High in Remote Sensing and in Products and Technologies Applications

<u>Japan</u> - Medium to High in all elements except System Infrastructure Management and Space Station related elements

TABLE 5.2: TIER 1 NATIONS AD 2000 COMPARABLE POSITIONS

NATIONS / SPACE ENVIRONMENT ELEMENTS	CANADA (INTERIM)		UNITED STATES		ESA		FRANCE		GERMANY		JAPAN		USSR		CHINA	
	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000	1985	2000
PART 1 - SPACE SYSTEMS AND TECHNOLOGIES																
1. LAUNCH FACILITIES			P HIGH	P HIGH			P HIGH	P HIGH			P MEDIUM	P HIGH	P HIGH	P HIGH	LOW	P HIGH
2. SATELLITES & PAYLOADS	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	MEDIUM	P HIGH	P HIGH	P HIGH	LOW	MEDIUM
3. SPACE PLATFORMS	PLANNED		P HIGH	P HIGH	PLANNED	?	PLANNED	?	P PLANNED	?	PLANNED		P HIGH	P HIGH		
4. TRANSPORTATION (SHUTTLE, OTV)			P HIGH	P HIGH	PLANNED	?	PLANNED	?			PLANNED		P HIGH	P HIGH		
5. GROUND SEGMENTS	P HIGH	P HIGH	P MEDIUM	P HIGH	LOW	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	P HIGH	P HIGH	P HIGH	LOW	MEDIUM
6. SYSTEM INFRASTRUCTURE MANAGEMENT			PLANNED	P HIGH	PLANNED	?							P MEDIUM	P HIGH		
7. SPACE SYSTEM DEVELOPMENT	LOW	MEDIUM	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	MEDIUM	MEDIUM	MEDIUM	P HIGH	P HIGH	P HIGH	LOW	MEDIUM
PART 2 - APPLICATIONS & APPLICATIONS TECHNOLOGY																
1. COMMUNICATIONS	P HIGH	P HIGH	P MEDIUM	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	MEDIUM	P HIGH	P HIGH	P HIGH	LOW	MEDIUM
2. REMOTE SENSING	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P HIGH	P MEDIUM	HIGH	MEDIUM	P HIGH	P HIGH	P HIGH	LOW	MEDIUM
3. PRODUCTS & TECHNOLOGIES	PLANNED		PLANNED	P HIGH			PLANNED		MEDIUM	HIGH	PLANNED	HIGH	P MEDIUM	P HIGH		
4. RESEARCH	MEDIUM	MEDIUM	P MEDIUM	P MEDIUM	P HIGH	P HOGH	MEDIUM	MEDIUM	LOW	LOW	MEDIUM	P HIGH	P MEDIUM	P MEDIUM	LOW	LOW

USSR - Medium to High in System Infrastructure Management and in Products and Technologies Applications

China - Low to High in Launch Element and Low to Medium in other applicable elements.

Table 5.2 Tier 2 Nations A.D. 2000

Utilizing the same Space Environment Structure employed in Table 5.1, Table 5.2 identifies the Tier 2 nations and their areas of focus for the AD 2000 period. As has been indicated some of these, in particular Brazil, India, Indonesia, and Australia are more advanced than the others. UK is perhaps a special case. Because of the close relationships between UK and ESA a good deal of the British involvement in space falls under ESA in this classification. The authors would agree that taken in its own right UK would be classified in the Tier 1 category.

For the most part in the Space Systems area the Tier 2 nations are focussed upon Satellites and Payloads and upon Ground Segments. India does reflect aspirations of development of launch capability however. Summarization of element primary focus is:

Satellites and Payloads - Australia
- India
- UK
- Brazil

TABLE 5.3

TIER 2 NATIONS AD 2000

SPACE ENVIRONMENT ELEMENTS / NATIONS	AUSTRALIA	INDIA	UK	BRAZIL	SWEDEN	KOREA	INDONESIA
PART 1 - SPACE SYSTEMS AND TECHNOLOGIES							
1. LAUNCH FACILITIES		X					
2. SATELLITES & PAYLOADS	X	X	X	X			
3. SPACE PLATFORMS							
4. TRANSPORTATION (SHUTTLE, OTV)							
5. GROUND SEGMENTS	X	X	X	X			X
6. SYSTEM INFRASTRUCTURE MANAGEMENT							
7. SPACE SYSTEM DEVELOPMENT	X						
PART 2 - APPLICATIONS & APPLICATIONS TECHNOLOGY							
1. COMMUNICATIONS	X	X		X		X	X
2. REMOTE SENSING	X	X	X	X			X
3. PRODUCTS & TECHNOLOGIES					X		
4. RESEARCH							

Ground Segments	- Australia - India - UK - Brazil - Indonesia

In the Applications area most of the focus among Tier 2 nations is on Communications and Remote Sensing as follows:

Communications	- Australia - India - Brazil - Korea - Indonesia
Remote Sensing	- Australia - India - UK - Brazil - Indonesia

Sweden reflects a special interest in Microgravity Applications.

5.3.2. Features and Behaviour of the A.D. 2000 Marketplace

The foregoing tables link up the sellers (suppliers), and buyers of space hardware and applications products through the 1985-2000 period. Chapter 3 has dealt in some detail with the space plans of many of these seller and suppliers. From this analysis it would seem probable that the world space scenario that would be viewed by Canada would be characterized by:

- Japan and China assuming more significant roles in Space Systems and in Space Technology not only in meeting their own national requirements, but, in the case of Japan a new major competitor could enter the marketplace;

- the communications satellite North American and European marketplace would seem to be dominated by Hughes, Ford, RCA, MATRA and British Aerospace. Japan would appear to be in a position for potential domination of the Far East marketplace. Tier 1, non-major nations would be seen to perform a role as subcontractors to North American, European and Japanese prime contractors. Prime contractor opportunities for Tier 1 non-majors would seem to be possible in third world and developing nations (e.g. Brazilsat - Nigersat).

- the demand for products from Space Applications on the part of buyer nations increases significantly but the sources of supply also increase and all respond to the market demand in a more competitive environment. This competition would be very stiff in the area of Remote Sensing, but the market demand will be shaped by the competence of the users to utilize the data products; in some cases by data exclusivity; and in other cases by the application of complementary technologies and techniques in terms of computers, high speed communications networks, and artifical intelligence. In this sense market demand may be extremely specialized and buyers extremely selective as well as price-conscious.

- observing the trend of recent events in the United States governments will tend to transfer more and more of the applied science and development toward the private sector as the commercial viability of the intiatives which have been government funded becomes more apparent and shows signs of being able to attract private sector investment. Nonetheless governments will continue to view a large portion of space activity somewhat in the light of a sovereign national activity and would be expected to institute protectionist policies and other measures to obstruct the industrial multi-nationalization of space.

- communications would continue to be viewed as a sovereign national preserve and nations would strongly resist relaxation of regulatory policies and mechanisms applicable both nationally and internationally. We consider the regulatory factor to be extremely important and have attached a special section on this subject as Appendix 4 to this Report.

- it may be expected that the A.D. 2000 marketplace would be marked not only by nations taking protective measures through regulation but by adopting other exquisite forms of non-tariff barriers to protect their national industry. Large R&D programs may be mounted as defensive strategies against competitors and to force obsolesence (it could be argued that areas of the Space Station program generate redundancy and obsolesence among elements of current and planned satellite systems). Another strategy is to negotiate the positioning of ground stations in another nation's territory

- the achievement of sales in the international A.D. 2000 marketplace inescapably will entail extremely high marketing and business development costs and the conditions of sales will be marked by very intricate financial arrangements which may severely test the ingenuity of governments to execute in what might be seen as a "buyers market".

5.3.3. The Obtainable Market 1985 - 2000

The review of the space plans of the nations which make up the A.D. 2000 marketplace both as suppliers and consumers and the specialist roles of the suppliers as viewed in the present and the future from space plans, suggests that Canadian supplier opportunities would most likely have prospects for success if focussed upon:

China - Communications and Earth Observation Satellites
- sensor technology, data communications, switching, data processing, earth segments and instrumentation
- market strategy - education and technology transfer

Developing Nations

- communications and Remote Sensing
- systems integration, mobile communications, data processing, earth terminals, switching, consulting
- market strategy - education, technology transfer
  - prime and sub-contractor roles achievable

Europe

Should Canada remain associated with ESA?

- communications and Remote Sensing
- extension of current collaborative intiatives - processing, solar arrays, systems integration, space mechanics and mechanisms, earth terminals
- market strategy - collaborative programs in sub-contractor role (opportunities for prime contractor role are remote)

United States

- communications, remote sensing, military systems, space station, materials processing
- mobile communications, high frequency (EHF) transponders, power systems, antennae, switching, system integration, earth segments, space platform construction and space system maintenance, radar, optical imaging, infrared imaging, laser technology, tactical command and control systems, space mechanisms
- market strategy - Canadian - US Industry alignments, joint R&D initiatives, participation in US military programs (EHF communications, space-based surveillance) - subcontractor role, joint North American Defence Systems.

5.4 Effectiveness in Canadian Market Strategy

It is not within the mandate of this study to presume to recommend the form and content of a future Canadian Space Program, or the long-term strategy for such a program. It is clear, however, that some continuous, concerted, and integrated marketing plan and program will be essential to address the complex and competitive market of the A.D. 2000 period. This suggests the mobilization of the major players in government, industry and the university sectors.

Based upon the present fundamental objectives of the Canadian space Program,

- the fulfillment of national needs in space applications;
- the establishment of a viable indigenous space industry as a national advanced technology asset;
- the conduct of space science activities as a member of the world science community;

it is obvious that the cross-impact of programs supporting these is so substantial that a continuous coordination is required coupled with considerable flexibility.

The proceeding Chapters have analysed past and present space program and achievement and have described the A.D. 2000 space scenario as the background from which the future Space Progream might be formulated. Presumably such a future program is developed within some level of resource availability and this involves difficult choices. The fulfilment of national needs (first objective) may involve a very difficult Make or Buy decision. One will always be able to identify national need "deficiencies". Development and enhancement of a Canadian Space Industry Base as a national asset suggests a maximum of Canadian Content in meeting national needs, combined with support also of other advanced technology areas which are space-industry related, (e.g. telecommunications and computer technologies). Since the Canadian market in the consumer sense is not sufficient to maintain a wholly viable Canadian Supply industry, considerable support must be provided to enable the Canadian Space Industry to develop and maintain the international market niches that will achieve the appropriate level of viability to generate the socio-economic returns that justify the cost of investment. These interrelated but frequently competing requirements also constitute a problem of choice between the first and second objectives of the Canadian Space Policy and Program. The third objective is more tractable if taken in the context of previously rationalized Objectives 1 and 2.

On this basis it would be assumed that Canadian Space Policy and Program Strategy would be a combination of Government specified and articulated programs and objectives, together with associated space industry program objectives, strategies, and activities which permit the industry to exploit its technologies and product advantages in the world marketplace with the assurance of full-scale government support in marketing and business development. Any opportunity for the firms which comprise the Canadian space Industry to formulate effective and productive business plans with the benefit of a coherent and articulated government plan and visible management structure would be considered by many to be a substantial step in responding to the anticipated A.D. 2000 Marketplace. In this context the reader may recall Sections 2.3.2 and 2.3.3. of Chapter 2.

In such a framework (and in conformity with the stated objectives of the Government Space policy) the role of government might be seen to be the identification and selection of national needs and the subsequent definition (through consultation) of those needs to maximize the utilization and development of national space and space-related industry.

The further role of government in this context might be seen to provide the support and facilities infrastructure to the industry which would provide the opportunity for the industry, often through its own intiatives, to exploit its market advantages:

- provision of central facilities (e.g. DFL etc.)
- special space industry and space-related industry enhancement programs such as research and development, marketing and business development support.
- international financing arrangements
- marketing assistance at the international political level
- market defensive strategies and regulation

Taken this way the Canadian Space Program might be seen as a balance between defined national needs shaped to favour indigenous industry combined with a structure of support programs and initiatives to assist the industry in taking its initiatives to achieve an international sales volume sufficient to provide a return to national socio-economic objectives. The record indicates that government on its own has not always been a perfect marketing agency. Implicit in a concept of this kind would be the notion that the national space program would involve some integration of government and industry business planning so that the industry would be able to formulate its operational business plans in an environment of minimum uncertainty and indecision. Some multi-sector business development and marketing mobilization could prove to be a very powerful instrument in gaining advantages to Canada in the A.D. 2000 context. Such an instrument could be signifcantly beneficial both within Canada and in international perceptions of Canadian intentions.

5.5 Summarization

Setting out to provide background analysis relative to the study and definition of a future Canadian Space Program for Canada this report has:

- examined the future space environment scenario in terms of which such a future program would be developed
- examined the impact of that environment in terms of current Canadian programs, projects and options (and major issues and key technologies).

taken as a measure of market demand ecxept in situations involving government provided public services. This suggests that the Canadian public and business interests may not be sufficiently conditioned to the potential for investment in user-oriented space applications in communications and remote sensing. There may be doubts about the ability of the Canadian market to provide an adequate return on investment compared to alternative investments. In this case private sector investment will flow to international market initiatives. Similarly private sector investment will flow to Canadian suppliers who are able to capture profitable international market niches. Until higher levels of investment can be attracted from the private sector, government must meet the the deficiency thus created, but must optimize its strategies to reduce the deficiency progressively.

The development of future and competing technologies (focussed on the A.D. 2000 environment) makes up an impressive list in which the cost of exploiting and maintaining the "competitive edge" in present Canadian capability areas may well leave little in the way of resources to undertake new technology development in which competitors may have better prospects. In this sense Canadian new initiatives will have to be quite selective, providing almost sure prospects for specific application if the cost of undertaking them is to be justified. The future space marketplace will see a premium placed on technology already developed and in place in preference that not yet developed. The market will be highly sensitive to price and a considerable government intervention would seem to be a crucial requirement for price competitiveness.

This complex milieu in which a future space policy and program is to be defined suggests the need for considerable emphasis on the Government - Industry partnership which is essential in meeting the goals of each sector. In formulating policy and program the existence of some central program management responsiblity center in government with which industry can deal in the development of its business plans and initiatives might seem to be the instrument for producing the best mutually beneficial space plan initiatives and execution.

* * *

APPENDIX 1

COMMUNCATIONS

The first of these is that while it should be appreciated that the military use of communications satellites will be a major, if not predominant, factor of future world wide communications policies and trends, it is assumed that such applications, including those by the United States, by NATO and by other national entitites as well as Canada, will be covered in depth by inputs from the Department of National Defence. Thus this portion of the study will not address military uses, other than to identify their existence on the relevant matrices.

The second assumption is that while it is recognized that the activities of the USSR in space communications are probably greater in total than those of the rest of the world, these USSR space communications activities:

- are apparently predominantly military in character
- have only a comparatively minor impact on Canada's commercial activities, primarily from a possible competitive impact in trade with some specific third world countries.

Thus the activities of the USSR will not be considered in detail, but again will be included only on the relevant matrices.*

In considering the major participants in international satellite communications, their policies and trends, four distinct groups of operational organizations have developed over the 20 years or so since the first geostationary telecommunications satellite, SYNCOM-3, commenced operations. These are:

- International and regional operating organizations typified by Intelsat, Inmarsat and Eutelsat.
- National and regional space agencies that typically carry out research and development, the planning of major national initiatives and frequently the provision and operation of launch facilities. This group is typified by NASA and ESA, and by the recently authorized United Kingdom Space Agency.
- National public or private organizations or consortia operating domestic satellite systems. This group is typified by

TABLE 1

TRENDS IN SATELLITE COMMUNICATIONS TO 2000

CURRENT MAJOR PARTICIPANTS AND THEIR ACTIVITIES

MAJOR INTERNATIONAL PARTICIPANTS	MAJOR AREAS OF ACTIVITY				MAJOR SYSTEMS AND STATUS					
	R&D	MAN	LAUNCH	USER	6/4 GHz COMMS	14/12GHz COMMS	EHF COMMS	DBS	MOBILE SAT	MIL C^3
EUTELSAT				x		C-G				
INTELSAT	x			x	C-M	C-G				
INMARSAT	x			x					C-M	
ESA	x		x			P-G	P-G	P-I		
NASA	x		x	x					P-I	C-G
CANADA	x	x		x	C-M	C-M	P-G	C-I*	P-I	
CHINA	x	x	x	x	P-G					
FRANCE	x	x		x	C-M	C-G		P-I		C-G
GERMANY	x	x		x				P-I		
INDIA	x			x	C-G					
ITALY	x	x		x			P-G			
JAPAN	x	x	x	x	C-M		C-G			
U.K.	x	x		x				P-I		C-G
U.S.A.	x	x	x	x	C-M	C-G	P-G	P-I	P-I	C-G
U.S.S.R.	x	x	x	x	C-M	?	?	?	?	C-G
ARABSAT				x	C-M					
PALAPA				x	C-M	P-G				
TELE-X				x		P-G		P-I		

Note: Major Systems: Current (C), Planned (P)
Status: Growing (G), Mature (M), Indefinite (I)
* Use of Anik C in DBS mode

in the period 1986 to 1993. Thus a number of these satellites will still be operational in the 21st century. It should be noted that in common with all recent Intelsat satellites, Intelsat VI will carry subsystems provided by major subcontractors in Canada, France, Italy, Germany, the United Kingdom and West Germany. Intelsat thus provides much "bread and butter" work for many of the major space industry manufacturers throughout the world.

Intelsat is a forward thinking organization and fairly detailed plans are already in hand for the Intelsat VII series with initial launch proposed for 1993 and continuing through to the 21st century. The configuration of this satellite series therefore provides an excellent indicator of turn of the century trends and communications satellite applications and technologies. It is noted with interest that the number of 6/4 GHz transponders has been reduced to 48 from 62 in Intelsat VI, whilst the number of 14/12 GHz transponders is increased from 24 to 48. A potentially important trend is the fact that the estimated spacecraft weight, despite increased transponder and switching capacity, is down from 4,800 lbs to 3,000 lbs. The trend toward greater flexibility of use by the provision of small zone beams, by onboard switching, and by the use of single sideband time domain multiple access together with single channel per carrier dedicated transponders is continued.

Until very recently Intelsat had, by agreement, a monopoly position for international communications satellite service. Although this has been modified by the licensing of an alternative organization proposing the carriage of transatlantic international traffic, operational service has yet to commence and the impact on Intelsat operations remains to be seen. Further details are given below under the section entitled "The Regulatory Environment".

A second major international operating organization is that of Inmarsat, the acronym for the International Maritime Satellite Organization. Inmarsat provides communications via satellite to the shipping and offshore industries around the world. Services include telephone, telex, facsimile and data communications. Its headquarters is located in London, England, as compared with the Washington headquarters of Intelsat. It is financed by the majority of nations with major merchant fleets, with membership of now over 40 nations. Thus more than 85% of the world's merchant shipping gross tonnage belongs to nations that are members of Inmarsat with major ownership (23.4%) being by the

United States with the Soviet Union being the second largest owner (14.1%). The organization was created in 1979 and took over its predecessor organization, Marisat, in 1982.

Currently three types of satellites are used, Marisat leased from Comsat General, Marecs leased from ESA and facilities on board Intelsat V-F5 leased from Intelsat. The satellites are in geosynchronous orbit over the Atlantic, Indian and Pacific oceans. The frequencies used are in the 1.5 GHz band and the 6/4 GHz bands.

There are in the order of 15 major Inmarsat shore stations around the world and several thousand shipboard terminals. These shipboard terminals are typically 1.2m in diameter, although both larger and smaller terminals are planned to provide users with the choice of increased service or decreased cost. Frequently double hop ship-to-ship links via a shore station are made in a truly world-wide ship-to-ship service. Currently the trend is for Inmarsat to lease space in the Intelsat satellites taking advantage of the precise station keeping of these satellites. Future plans call for the launching of 9 dedicated satellites, each with a 10 year design lifetime, over the period 1989 to 1991. The last six of these will still be in service at the turn of the century. It is planned that these will be comparatively small satellites with a weight of some 1,200 lbs. While it is expected that there will be greater emphasis on data carriage and more onboard switching to provide flexibility of operation, no other major trends are foreseen. The number of satellites planned however points to the virtually ubiquitous use of the communications satellite medium for all shipboard traffic in the future. It should also be noted that Inmarsat satellites can, and are being used, by aircraft as well as ships, and has the potential for limited land mobile use in some areas.

The final entity which will be addressed under this heading is a regional operating organization, Eutelsat, the acronym for the European Telecommunications Satellite Organization. As indicated by its name Eutelsat has the mandate and responsibility of providing international telecommunications, business and to an extent broadcast satellite services to members of the European economic community. As such it works very closely with ESA and to some extent can be looked upon as the telecommunications operating arm of that organization.

Eutelsat operates the European Communications Satellite (ECS) series of satellites. These provide satellite links to route the international telephone traffic within Europe, and the interim (low power) DBS service to enable the European Broadcasting Union to expand its Eurovision system of TV program exchange. In addition they provide satellite business communications throughout the EEC.

ECS-1 was launched in 1983 by ESA and has been operated since by Eutelsat. To overcome the interference problems of the 6/4 GHz band which is shared with terrestrial microwave, all 12 transponders operate in the 14/12 GHz band. This satellite has a designed lifetime of 7 years and as followed by ECS-2 launched earlier this year (1985) and ECS-3, 4 and 5, are expected to be launched over the next 18 months period. The plans of Eutelsat after this are not at this time very well defined but could well make use of the Olympus multi-band communications satellite. It should perhaps be noted that Eutelsat future policies are not so clearly defined as those of Intelsat or Inmarsat, possibly due to the varying requirements and aims of the members of the European Economic community. It should be also noted that many EEC members have their own national communications satellite manufacturers and operating organizations that operate to a greater or lesser extent in virtual competition to Eutelsat. It should however be noted that currently the major future thrust is toward business communications and possibly mobile satellite service.

National and Regional Space Agencies

This group of participants in international satellite communications consists of the National Aeronautical and Space Agency (NASA) of the United States, the European Space Agency (ESA) and the recently authorized United Kingdom Space Agency.

As the latter organization is still in its initial organizational stages, it will not be discussed in detail, other than to note that the United Kingdom has drawn upon the positive experience of the United States and Europe to coordinate its overall space activities by this mechanism.

NASA and ESA both have the mandate of the coordination of overall space activities within their respective jurisdictions. While this of course covers space activities as a whole, and not merely space communications, the latter are a substantial segment of the mandate of both agencies. While neither agency normally participates in the commercial operations of space communications, both are extremely active in research and development, in the design and operation of experimental or demonstration communications systems, and of course both operate large launch facilities. Thus these agencies have a major impact upon the future trends of satellite communications. In fact with Intelsat they can perhaps be said to be major catalysts in the field.

NASA approaches these responsibilities by initiating and participating in a wide-range of communications oriented projects. Currently these include:

- Tracking Data Relay Satellite System (TDRSS)
- Basic Research and Technology Development
- Advanced Technology Development for ACTS
- Technical Consultation and Support
- Further Development of Search and Rescue Satellite Systems
- Development of Communications Sub-systems:
  - electron beam amplifiers
  - Solid State devices
  - antennas
- Research into the Large Antenna Systems.

NASA's plans for the medium term future include participation in MSAT, the development of large geostationary platforms, and direct satellite sound broadcasting.

It is perhaps appropriate to quote from NASA's published telecommunications policies which are:

- Develop high-risk electronics technology useful in multiple frequency bands to satisfy the communications needs of NASA, other government agencies and U.S. industry

- Initiate mobile satellite commercialization program to develop; technology, commercial markets, terminal hardware & networking

- Improve efficiency and economy in processing large volumes of data.

It should be noted that there has historically been very considerable liaison and cooperation between NASA and all segments of Canada's space industry. Many members of Canada's private sector Space Industry are recipients of NASA contracts; there have been major cooperative ventures between NASA and the Communications Research

Center of DOC, for example the HERMES Advanced Technology Satellite; and DOC and NASA are working together on plans for MSAT, from a government viewpoint, with Telesat Canada and a U.S. commercial entity handling the private sector operators.

It can be said with some validity that NASA's future plans and activities in the development of new communications satellite technologies cannot be ignored in the development of future Canadian strategy in this field.

The European Space Agency (ESA) of which Canada is a contributing member adopted a resolution for a long term European space plan on the 31st of January 1985. This space plan covers the period until the end of the century and identifies in considerable detail the approaches planned by Europe. The resolution of course covered all aspects of space activity, but for this report it is perhaps most appropriate to quote from the telecommunications segment of the European Space Agency council background papers which lead to the resolution.

With minor editing in the interest of succinctness, the ESA telecommunication policy for the period until the end of the century is:

> <u>The Telecommunications Program</u>
>
> In the field of Telecommunications, the general objective is to ensure that European industry can maintain and expand its competitive position in the space communications market, and that Europe can operate with the necessary efficiency and independence in other space fields.
>
> More specifically, the fulfilment of the above broad objective requires a well pointed Agency's effort in accordance with the following program objectives:
>
> - to develop and untimately test in orbit specific advanced space techniques which will contribute to the long term development of established communications systems;
>
> - to demonstrate and promote new space communication services for the expansion of European space communication activities and the development of a larger European commercial market, as the necessary prerequisite of any successful export effort;

- to support other space missions and applications, such as Space Station and remote sensing, through inter alia the development of a European in-orbit communications infrastructure (Data Relay).

The program proposal consists, therefore, of the following activities:

- Development of new telecommunications systems including;
  - specific payload and spacecraft systems covering new techniques such as a on-board signal processing and satellite clustering;
  - advanced systems and technology support;
  - experiments with existing satellites and field trials.
- In-orbit demonstration missions including:
  - a technology experiment around 1990;
  - an advanced orbital test satellite system for the year 1993 or beyond.

In terms of satellites to be launched Table 2 gives a summary of planned and proposed ESA telecommunications spacecraft missions for launch during the period 1988 to 1999.

TABLE 2

SUMMARY OF PLANNED AND PROPOSED ESA COMMUNICATIONS SPACECRAFT MISSIONS 1988-1999

PROGRAM	PHASE DECISION	PHASE C/D DECISON	LAUNCH DATE	TOTAL COST MAU	NO. OF SATELLITES
Olympus II	1984	1985	1988	170	1
Advanced OTS-1	1986	1987	1991/2	666	2
Advanced OTS-2	-	-	1998/9	800	2
DRS-1	1987	1989	1994/5	528	2

It is perhaps appropriate to emphasize that there has been considerable criticism of the ESA telecommunications policy as emphasizing the space segment at the cost of the development of high efficiency low cost ground stations. Currently the European earth station market is dominated by U.S. and Japanese products and as mentioned previously, from the economic viewpoint, the earth station segment of space communications provides the greatest opportunity for economic benefit. For example one estimate of the European ground station market is $2.5 billion Canadian by 1993.

National Public or Private Organizations or Consortia Operating Domestic Satellite Systems

The most well known of this group from the viewpoint of Canadian audiences is of course Telesat Canada. However as Telesat Canada activities will be covered in detail by the Communications segment of the ISC working group it will not be covered here other than to identify the fact that operationally, if not necessarily financially, it has been extremely successful and at the end of the century is expected to be operating Anik E and F series of satellites, being follow-ons of the current 6/4 GHz Anik D's and 14/12 GHz Anik C's. It is not expected that there will be major differences in approach of these fourth generation satellites. In addition it is expected that Telesat Canada will be operating an M-Sat and will be using a portion of the 14/12 GHz satellites to provide interim DBS service. At the turn of the century plans will be finalized for follow-ons to the Anik E and F and M-Sat, and could possibly follow the multi-purpose satellite approach, providing that this concept had previously been well proven in other areas. Also at the turn of the century it can be validly expected that Telesat Canada will be giving serious consideration to the inclusion of EHF facilities on its new satellites, and to the inclusion of data relay and switching facilities, perhaps to downlink high-speed data from remote sensing satellites such as Radarsat.

While there are many nations who have developed or are developing their own domestic communications systems in one form or another, in the interest of brevity, only those of significance, and those likely to have an impact on Canada's own strategic space policies, will be addressed in this section.

The dominant nation in domestic satellite operations is currently the United States, and there is every sign that this domination will continue, perhaps with some serious competition from Japan, and very considerable imitation by many nations throughout the world.

It can be arguably stated that the dominance of the United States domestic communications satellite industry, which commenced operation some four years after Canada's domestic satellite system, is due to the FCC's open skies policy that enforces the minimum regulatory restraint consistent with the minimization of radio frequency interference, good technical operating procedures and reasonable financial viability. This comparative lack of restraint led first of all to very significant use of domestic satellites by the new Pay-TV industry, the development of so-called TV broadcast super stations and the use of satellites for video conferencing. U.S. businesses suddenly had a nation-wide wideband distribution technology at very reasonable cost and made full use of it. Many new types of business systems developed and while there were of course the usual "shake outs" typical of booming free enterprise in a high technology area, the survivors are currently very profitable, are expanding, and providing very considerable market pull for the development of new satellite communications technologies.

Major organizations such as RCA and Western Union, the American Satellite Company, Satellite Business Systems, to name but a few, were established to develop and operate private sector satellites to provide services to a wide range of customers. Many operating companies in a large range of innovative services have sprung up and are making maximum use of the opportunities provided by satellite communications.

A further policy aspect which is worthy of note is that of the close cooperation between American federal government operating agencies and private sector operating agencies. For example NOAA gathers data from its low earth orbit satellites and contracts with RCA Americom to distribute this data to users via a Satcom geostationary communications satellite. This policy of close cooperation, which shows no sign of diminishing, provides cost-effective methods of maximizing spacecraft utilization.

This dynamic approach to the utilization of communications satellites also has its disadvantages. Orbital slots in the geostationary orbit are of course a non-renewable resource and the proliferation of U.S. satellites is rapidly exhausting available orbital positions suitable for North and South American domestic communications satellites. This has at least three major impacts as follows:

- it provides considerable incentive to develop technology to reduce satellite spacing, to develop new frequency bands and to make most effective use of the spectrum

- it also provides the incentive to develop alternative terrestrial technologies such as fibre optics

- it is the source of considerable international concern, particularly from developing countries in South America who consider that their valid share of the geostationary orbit is being pre-empted by the U.S. in particular and the highly developed nations in general.

Notwithstanding this there is every sign that U.S. space policies will continue essentially in their current form into the next century, with emphasis on multi-purpose, innovative spacecraft with close spacing and considerably more switching than the present generation, thus emphasizing those areas where there is little competition from terrestrial wideband long haul communications systems such as fibre optics.

Another nation in the forefront of domestic satellite development is Japan. A late comer into the field, its first domestic satellite, CS-2A, launched at the Japanese launch facilities at Tanegashima Space Centre, this satellite was the result of many years of experimental communications satellite operation.

Thus it is not unexpected that Japan's domestic satellite series, which now consists of two satellites, the CS-2A launched in February 1983 and the CS-2B launched in August 1983, are highly innovative in their concept and operation and are thus excellent pointers for the future.

The CS-2 series are hybrid satellites, operating in two frequency bands, but in contrast with hybrid satellites launched by other nations, operate in the 30/20 GHz band and the 6/4 GHz band. Each satellite has two transponders in the 6/4 GHz band and six in the 30/20 GHz band.

The previous experimental satellite, Sakura, has been a useful training tool for developing methodologies for operating 30/20 GHz satellites under non-optimum weather conditions. In the CS-2 satellites these transponders are used as field TV relays and remote island relay circuits. They are also used for two-way voice and data traffic in the TDMA mode. A further use of the 30/20 GHz transponders is for the satellite digital communications system (SDCS) permitting a private network operator, say a large company, to set up and operate a private satellite data network to the company offices spread throughout the multiplicity of islands that make up Japan. This new private circuit is called multiple access closed network (MACNET) as the circuit configuration is similar to that used for a local area network.

Another innovative feature of the satellites is the method of use of the 6/4 GHz band. It will be appreciated that this band is, by ITU agreement, shared with terrestrial microwave systems. Thus the problem of frequency coordination between satellite and terrestrial systems is a significant one, particularly in Japan where terrestrial microwave is used very extensively.

To minimize interference problems the CS-2 satellite series uses a spread spectrum multiple access (SSMA) communications system. This spread spectrum system reduces power levels very significantly by spread modulating a PSK transmission 1,023 times a second with a very high spread code series. The system as a whole consists of a master earth station and a very large number of small earth stations. It uses fairly standard TDMA transmissions from the master earth station to the small earth stations and SSMA for the link between the small earth stations and the master station.

These innovative approaches are indicative of the dynamic approach that Japan is taking to the use of communications satellites. Considerable work has already gone on in the development in Japan of yet a higher frequency EHF band, the 50/40 GHz band. Japan's plans for further launchings over the next 15 years include a further six satellites in the CS series, the CS-3A and 3B, the last of which will be launched in 1999 and have a 7-year lifetime. This series has transponders only in the 30/20 GHZ and 50/40 GHz bands. Somewhat in parallel with this series is the INS with transponders in the 14/12 GHz band as well as in the EHF bands. The INS series is planned to consist of eight satellites in total with launch dates spread between 1989 and 1999.

It is interesting to note that despite the use of spread spectrum 6/4 operation in the CS-2 series, neither the CS-3 or the INS series will carry any 6/4 GHz transponders.

The United Kingdom does not currently operate a domestic satellite system although for many years it has been developing a Direct Broadcast Satellite series, currently called UNISAT. This will be operated, after a planned 1987 initial launch, by United Satellites Limited, a company formed by British Aerospace, General Electric Company (U.K.) and British Telecom. Three satellites have been ordered with launches planned between 1987 and 1994. The satellites operate solely in the 12/14 GHz band and have high power DBS-type transponders.

The development, launch and operations of these satellites has been significantly delayed by the varying policies of the last few years of the British government, once more indicating the need for a well-defined stable national space strategy. It is hoped that the setting up of a United Kingdom space agency will provide this stable environment.

France has recently launched the first in a five satellite series of domestic satellites called Telecom-1. These are again hybrid satellites with four transponders in the 6/4 GHz band, two transponders in the military satellite 8/7 GHz band and six transponders of reasonably high power in the 14/12 GHz band. In addition France is launching a direct broadcast satellite series, the TDF series, commencing later this year (1985) and continuing until a final launch planned for 1994.

West Germany is also launching very similar DBS satellites designated TV-Sat over a similar time period.

Any dissertation on domestic satellites would not be complete without a brief review of Insat, India's multi-purpose communications, broadcasting and meteorological satellites. This satellite series is a remarkable achievement, considering the individual mission complexities and the fact that all three systems are contained in a medium-class satellite. The telecommunications functions include normal telephone and television point-to-point services. Direct television broadcasting service, and radio program distribution is also provided. The final mission is that of a weather satellite using a meteorological radiometer scanning the entire coverage area over a period of 30 minutes with 4,000 picture elements. Insat-1B became operational in October 1983 after the loss of Insat-1A. The insurance claim on the latter satellite will be used in part to launch an Insat-1C in 1986. A new series, Insat-2, is planned for launch in 1989, with the series continuing until a final launch in

1998. The Insat series is indicative of innovative low-cost design to meet specific national needs with a multi-purpose spacecraft.

In concluding this segment on domestic satellites, the general trend toward the use of such satellites should be emphasized. Recently Brazil has initiated its satellite system and many other countries such as Nigeria, Italy, Australia, Mexico, Luxemburg, Ireland, People's Republic of China, Argentina, Colombia, Pakistan and South Korea either have domestic satellites launched, under active development or planned.

Groups of Countries Operating Satellites for their Mutual Benefit

This final group of participants in space communications, while less well-defined than the others, appears to be a developing segment of users, particularly among the third world countries, and is a segment that could well have a significant impact upon international negotiations and trends for satellite spacing and technology in the future. It should be noted however that these satellites serve specific groups of countries bound together however loosely by some common factor such as religion, language or international agreement, and cannot be defined as international satellite links.

The first of these groups was initiated by Indonesia with its Palapa satellite system, initially launched in 1976. This series, Palapa-A, serves the whole of Indonesia, whose population is spread over some 5,000 islands covering a span of 3,000 miles, with television, radio, telephone, telegraph and government traffic. In addition several transponders have been leased to the Philippines for their internal use. Palapa-A operates in the 6/4 GHz band with 12 transponders. Palapa-B, planned for launch in 1986, after the failure of its initial launch, will serve Indonesia, Singapore, Malaysia, Thailand, and the Philippines. This series is essentially similar to the Anik D satellites, although a follow-on series will have 12 14/12 GHz transponders in addition to the 24 6/4 GHz transponders. The final launch of this follow-on series is planned for 1992. With a 10-year lifetime, these will still be operating at the turn of the century.

Arabsat is a consortium of Arab organizations spread throughout Africa and the Middle East with major funding by Saudi Arabia. Operating in the 6/4 and 2.5 GHz bands it provides standard point-to-point communications services and video services for community television distribution networks. Again an innovative approach to meet specific needs, this two-satellite series has recently been successfully launched. Arabsat is an indicator of the use of communications satellites to meet the common goal, of the many nations concerned, of economic independence of the region. Plans for a follow-on series include transponders in the 14/12 GHz band, with the follow-on series planned for launch between 1991 and 1996, each with 10-year lifetimes.

The Tele-X satellite is the precursor for the Nordsat series of satellites planned to distribute high power television and high speed data to the Nordic countries of Sweden, Norway and Finland. Planned for launch in 1987 it will be followed in 1989 by the Nordcom series that will serve Sweden, Norway, Finland, Iceland and Denmark. This four-satellite series which will be launched between 1989 and 1998, will have six transponders in the 14/12 GHz band and will also be used for direct broadcast television and data.

Other countries, including Australia, are examining the concept of multi-country use of satellites to off-set the initial high cost. It is expected that this trend towards international cooperation will continue and be a signficant factor in national communications satellite policies.

THE DEVELOPMENT OF COMPETITIVE TECHNOLOGIES

When originally conceived communications satellites filled a major need for the reliable international communication of wideband electronic information. Over the last 20 years it has more than fulfilled this significant niche. While there appears to be no apparent diminishing of the need for international communications of huge amounts of information, the crowding of the geosynchronous orbit, and the immense amounts of capital required for large satellite systems, together with the possibility of launch or satellite failure without the chance of repair has provided the incentive for the development of alternatives. The prime alternative technology so far developed is that of optical fibers. A natural development of long line technology, both terrestrially and under the ocean, the broad band optical cable has the advantage of making use of the significant infrastructure already in place for manufacturing, installing and operating long lines around the world. Recent deals between common carriers and major railroads throughout North America to make use of the extremely valuable railway rights-of-way has provided an additional thrust to this competing technology. It seems very likely that by the end of the century the majority of international long-haul voice, data and video traffic will be carried by fiber optic systems, with the more traditional relay type traffic via communications satellite being replaced by DBS, switched data, and similar type of satellite systems.

At the moment this appears to be the sole major technology that is likely to be a competitor to communications satellites in the next two or three decades, and even so fiber optics is likely to be a complementary rather than a replacement technology for communications satellites in the long-term. Each technology will fill the niche to which it is best suited, and in many cases a user of a particular electronic communication system will be unaware of the distribution medium used. In conclusion it should be mentioned that long-haul fiber optic two way communications system has the advantage of significantly shorter delay than a similar satellite communications system, a major factor in data and other two way communications.

NEW SATELLITE COMMUNICATIONS TECHNOLOGIES AND APPLICATIONS

In a dynamic industry such as space communications it is not surprising to find a wide range of developing technologies likely to significantly change the current situation by the end of the century, and to have a major impact upon any long-term strategic policy.

For ease of discussion these technologies have been separated into the following three headings:

- Evolutionary Technical Development
- New Approaches and Applications
- Technologies Aimed at Greater Spectrum Utilization and Efficiency

It will be recognized that to an extent the selection under these three headings is arbitrary and there is some overlap. The new satellite communications technologies that will be dealt with in this segment are tabulated under these three headings in Table 3.

TABLE 3

NEW SATELLITE COMMUNICATIONS TECHNOLOGIES

Evolutionary Technical Development

- Longer satelite life-time
- Higher satellite prime power capacity
- Improved low noise amplifiers, solid state high power amplifiers and microwave integrated circuits
- Low cost microterminals for thin route voice and data

New Approaches and Applications

- Molnya orbits
- Major switching capability within the satellite
- Repair, refuelling and refurbishing capabilities
- Multipurpose satellites

Technologies Aimed at Greater Spectrum Utilization and Efficiency

- Digital compression techniques
- Closer satellite spacing
- Spread spectrum, multiple access technology
- Development of new frequency bands

Satellite Communications Evolutionary Technical Improvements

Over the last decade or so there has been a general extension of the operational life of satellites. The limiting factor is primarily, but not exclusively, the station keeping fuel. Currently, communications satellites have between a seven to ten year design life time, and frequently live longer. While longer life time satellites can be developed, there is a significant trade-off between life time and up-to-date technology. Currently technology is developing sufficiently fast that a 10 to 15 year life time is considered to be the maximum before the satellite is technologically obsolete. It seen that from a technological view point communications satellites are by no means mature and thus it is considered unlikely that over the next several decades that satellite life times will be longer than around 15 years. It is likely however that improvements in attitude control will signficantly reduce the quantity of fuel required to give these life times and thus result in improved satellite efficiency.

Another evolutionary technological improvement is that towards higher prime power capacity of satellites through larger and more efficient solar panels. It is considered very likely that this trend will continue, although in a fairly fast evolutionary manner rather than in any revolutionary major break through. Most of the new approaches and trends towards spectrum efficiency detailed below will require greater power. Thus it can be predicted with reasonable confidence that communications satellites at the turn of the century will have solar power capacity several times that which is common today.

Earth station manufacturing techniques and specifications is another area where considerable, but evolutionary, change can be expected over the next 2 or 3 decades. With higher satellite power and the trend towards the KU and KA bands ground stations are likely to become a lot smaller, but have LNAs with extremely low noise temperatures and solid state HPAs. In addition manufacturing techniques will tend towards microwave integrated circuits and large scale integration thus permitting significant cost reductions and very large manufacturing runs.

New Approaches

The first new approach identified in Table 3 in fact belies this heading. It is the concept of the Molnya orbit for communications satellites to overcome the expected future congestion of the geostationary orbit. This specialized low earth orbit was one of the first used by the Russians for their early communications satellites. The orbit are inclined to the poles by the same angle that the earth poles is inclined to the earth's orbit about the sun, thus any satellite in this orbit will appear at one horizon, track directly overhead and set at the opposite horizon, thus requiring tracking in a single plane only. Other non-geosynchronous orbits require tracking in both planes with significant increase in earth station complexity. If a communications satellite was given a highly eliptical Molnya orbit with its apogee above the prime service area, it would remain in sight for almost 12 hours. Thus a constellation of three satellites would provide 24 hours coverage. Launching into a low earth orbit is less expensive than a geostationary orbit, and refurbishing and refueling again is less expensive.

Considerable research is currently going on towards efficient use of this type of orbit. However bearing in mind the likely vast increase in earth stations, and the problems of sighting and tracking a satellite in a Molnya orbit, it is expected that its use will be comparatively limited, and other ways of improving the utilization of the geosynchronous orbit will be more attractive.

A further new approach expected to be implemented over the next decade or so, and to be in significant use by the end of the century, is that of providing major switching facilities for telecommunications in the satellite itself. Satellite communications will thus move away from the simple "relay in space" leaving this field to fiber optics, and will provide the more sophisticated network functions directly at the satellite.

The next new approach to be considered is that of the concept of repair, refuel and refurbishing of geosynchronous communications satellites. Currently the life time of satellites is primarily limited by the fuel, by battery life time and by catastrophic failure of electronic components.

Over the last year or so the concept of refurbishing, refueling and repairing satellites from the STS has gained significant impetus. Considerable work has taken place on orbital transfer vehicles which would permit the "hauling down" of a geosynchronous orbit satellite to low earth orbit for repair, refurbishing and refueling by the STS. Bearing in mind the capital cost of satellites and their launch, the huge insurance premiums and the current short technological life time before obsolescence it is considered extremely likely that by the end of the century all satellites will have facilities for repair, refurbishing and refueling. This will of course have an extremely significant impact upon satellite economics as a whole.

The final new approach to be considered is that of multipurpose satellites. These can take two forms, the so called Hybrid communications satellites that operate in several bands, and those with functions other than communications such as INSAT. Although the concept, development and implementation of multipurpose satellites is not new, the commercial use of this concept has been comparatively limited. The main reason for this is that administrations have been extremely reluctant to "put all their eggs in one basket". However given the possibility of in-space repair, it is extremely likely that the economic advantages of the multipurpose satellite will ensure that this approach is in general use by the end of the century.

Techniques for Greater Spectrum Utilization and Efficiency

The first technique to be considered under this heading is that of digital compression. There is a general trend, throughout communications and not limited to satellite communications, of the digitizing of all electronic information. Other things being equal, this increases bandwidth requirements significantly, and thus makes for inefficient use of the spectrum available and of the geostationary orbit in general. Intelsat and many other organizations are carrying out significant research work towards the use of digital compression techniques on communications satellites. It can be predicted with reasonable confidence that the first decade of the 21st century will see the digitizing of virtually all satellite traffic and the ubiquitous use of digital compression techniques.

The next spectrum utilization concept to be considered is that of the development of new frequency bands. Already the trend has started, particularly in Japan and Europe, towards the utilization of the 30/20 GHz band. Japan has also developed plans for utilization on a commercial scale of the 50/40 GHz band. The use of both of these EHF frequency bands gives rise to significant propagation problems that are the subject of much current research. It is highly likely that by the turn of the century the use of the 6/4 GHz shared band will have dropped very significantly and the KU and KA bands will be in the majority use. Other advantages of these bands is of course greater information carrying capacity and the use of smaller-sized antenna dishes.

The major trend of greater and greater use of satellite communications gives rise to significant congestion in the geostationary orbit. This congestion has already seen satellite spacing reduce from 10^{o} to 5^{o} to 2.5^{o} spacing, with 2^{o} and 1^{o} spacings now planned. This trend of course puts significant pressure on the problems of coordination, antenna design and antenna pointing. It is however a trend which is unlikely to stop, and the turn of the century could well see major pressure for 1^{o} or even $\frac{1}{2}^{o}$ spacing.

A final technology that should be considered that impacts upon spectrum utilization and efficiency is that of spread spectrum multiple access. This concept is currently used by the Japanese CS-2 satellites to overcome the problems of interference with and by terrestrial microwave systems. It is considered that although this technique is likely to find some favour in the short term, it is unlikely to be considered a technique with long term advantages. Thus as the use of the shared 6/4 GHz band becomes less, it is predicted that this technique will slowly fall into disuse.

THE IMPACT OF THE REGULATORY ENVIRONMENT

Over the last 20 years of communications satellite activities, the regulatory policies imposed by national and international organizations have been shown to have a critical impact upon the development of any particular national industry, or international network. From a national viewpoint the regulatory approaches are typified by their diversity.

In Japan the traditional approach of very close liaison between government and industry has been extended to satellite communications and the current innovative systems tailored very closely to national needs are the result of a well-defined strategy backed up with the funds to implement it.

In the U.S. the development of domestic communications systems was a natural extension of the U.S. role in Intelsat, and in military space communications. It was perhaps serendipitous that the technology was right for development at the same time that there was a major regulatory trend on the part of the FCC towards very significant deregulation, and further coincident with the development of new services that could make use of space communications such as Pay TV, cable television and video conferencing. This happy confluence of events, backed up by the U.S. space manufacturing industry, has led to the current overwhelming dominance of the U.S. in the exploitation of all facets of satellite communications. The impact of this significant deregulation has gained so much impetus that it is now unlikely to change in the period under review. It should be noted however that such deregulation brings with it disadvantages as well as advantages.

In Europe the regulatory concepts pertaining to space communications have to a large extent been determined by the PT&T regulations in existence for the particular jurisdiction. This has tended to place emphasis on long-term experimentation with slow implementation periods and upon the constraints imposed by monopolistic considerations. Such regulatory restraints, together with the need for concensus regulations in such organizations as Eutelsat and ESA have had, in the opinion of many, a negative impact upon the timely and economically optimum development of satellite communications in Europe.

While it is considered that the past regulatory environment in Canada has had a significant, if not overwhelming, impact upon the development of space communications service industries and the traditionally poor utilization of Telesat's technically excellent domestic communications network, the development of this theme will be left to the DOC members of the ISC working group.

* * *

APPENDIX 2

REMOTE SENSING

APPENDIX 2

REMOTE SENSING

This appendix reviews the plans of the countries and agencies that are committed to serious long-term programs in remote-sensing by satellite. These programs are directed either to the space segment, and the provision of basic data, or the ground segment, for processing, interpreting and distributing remote-sensing products. The review of these remote-sensing programs is used to establish the trends and new directions in the subject which will influence the AD 2000 scenario. Reference material used for the review is isted at the end of the Appendix.

A reading of the current remote-sensing literature reveals a consistent, perceived need to move away from experimental programs and establish well-integrated operational systems that serve a global community with global data. Statements typifing this trend are as follows:

1. Remote sensing from space must and will change from a series of largely unconnected R&D thrusts to a coordinated global information technology.

2. As France, Japan and the United States move towards operational systems in space with strong economic as well as social objectives the constituency of users of remote-sensing information will broaden beyond the current, relatively small cadre of scientific researchers and scientifically-informed users.

3. Brazil is putting in place an ambitious, independent operational remote-sensing program.

4. Single instrument or discipline-oriented missions have been correct for the first decade of remote sensing but a multidisciplinary sensor approach with sensors operating simultaneouslyat microwave, infrared, visible and ultraviolet wavelengths will be needed for the next step forward.

5. Analysis of data from multidisciplinary sensor missions will be one of the major focuses for expert systems or Artificial Intelligence (AI)-aided systems.

6. A polar-orbitting space station with a full complement of remote sensors and onboard processing, capable of servicing a small number of dedicated free flyers and larger space platforms, is a logical scenario for the 1990's.

7. The synergistic use of numerous multidisciplinary sensors operating simultaneously in the visible, IR, UV and microwave bands implies new technologies for ground-based information processing, including advanced technologies for data acquisition, processing and distribution, plus space and ground-based expert systems.

For the purposes of this review the definition of an expert system given in reference 4.7 is used: an expert system is an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. The knowledge necessary to perform at such a level, plus the inference procedures used, can be thought of as a model of the expertise of the best practitioners of the field. Knowledge in an expert system consists of facts (public knowledge) and heuristics (mostly private). An expert system has three types of user interaction:

(i) user as a client - getting answers to problems
(ii) user as a tutor - increasing the system knowledge
(iii) user as a pupil - harvesting the knowledge base for human use

In theory, over time, an expert system could deliver a level of experties exceeding that of a single one of its tutors.

In 1983 expert systems (or AI) had 1200 followers - 800 to 900 observers and 300 to 400 serious investigators.

8. The wealth of data available will permit the creation of or improvements to models of global climate, ice budget and the hydrological cycle, biomass dynamics and the biogeochemical cycles. Typical sub areas are ocean dynamics, land cover and land use dynamics, global vegetation vigor, solar heating implications and atmospheric circulation and chemistry, including pollutants.

9. Expert systems plus robotics will provide self-management of space platforms between visits.

10. Future remote sensing platforms will be characterized by, in addition to a multitude of sensors,

(i) tens of kilowatts of power,
(ii) several tons weight,

(iii) hundreds of Mb/sec communications,
(iv) satellite to satellite communications to move information,
(v) large articulated platforms,
(vi) high precision pointing platforms,
(vii) active manned intervention.

11. The remote-sensing information system will be characterized by multidisciplinary data bases that researchers and users can access, add to, improve, and modify without destroying the general accessibility to the base.

The three most-recurring future themes are:

(i) synergistic use of multiple sensors on a global basis,
(ii) operational systems, with an economic return, using end-to-end concepts,
(iii) models to characterize "global habitability".

For the purposes of this analysis the field of remote sensing (from space) has been divided into five areas of application:

- Atmosphere, Meteorology and Chemistry (includes pollution),
- Land,
- Oceans, including sea ice,
- Surveillance, military,
- Surveillance, non-military.

The analysis is presented in the form of five tables. Table 1 contains capsule resumés of public policy statements by countries and agencies with respect to remote sensing over the next decade. Where applicable references to the five application areas are noted. Table 2 contains a list of the more unique future remote-sensing missions, with particular features noted.

The analysis of the resource material and Tables 1 and 2 yields answers to questions concerning the AD 2000 scenario, leading to Tables 3, 4 and 5.

TABLE 1: REMOTE SENSING POLICIES AND OBJECTIVES

COUNTRY	GENERAL	ATMOSPHERE: METEOROLOGY & CHEMISTRY	LAND	OCEANS	SURVEILLANCE	
					NON-MILITARY	MILITARY
UK	.R-S is next application area of commercial promise .national R&D program for radar R-S satellites & ground segment	Yes	Yes	Yes	None Known	None Known
France	.participate in ESA .long-term strategies to use R-S in operations			.ISMA/SPOT initiative in UN .arms control verification	.'military' SPOT abandoned	
FRG	.support national excellence .ESA should stick to R&D and leave operations systems to users .use space projects to foster international cooperation .promote innovation by using R-S in public systems .learn user needs by studying US & Spacelab .global monitoring		Yes	Yes	None Known	None Known

TABLE 1: REMOTE SENSING POLICIES AND OBJECTIVES (cont'd)

OUNTRY	GENERAL	ATMOSPHERE: METEOROLOGY & CHEMISTRY	LAND	OCEANS	SURVEILLANCE	
					NON-MILITARY	MILITARY
ESA	.independence .user priority .domestic market .world class results .prepare for substantial contribution of space & ground technology to public good .funding constraints force user priorities	Yes	Yes	Yes	No	No
Japan	.peaceful use .establish in-house fundamental technology of land and marine R-S satellites				Not Known	Not Known
USA	.maintain leader-ship .privatize to create industry & innovation .moving from R&D to capitalize on immense investment .expand private sector investment (cont'd)	see 'General'	see 'General'	see 'General'	.arms control verification	.high priority .takes precedenc over commercial

TABLE 1: REMOTE SENSING POLICIES AND OBJECTIVES (cont'd)

COUNTRY	GENERAL	ATMOSPHERE: METEOROLOGY & CHEMISTRY	LAND	OCEANS	SURVEILLANCE	
					NON-MILITARY	MILITARY
USA (cont'd)	.combine satellites into a global information system: need standards for system interfaces, compatible formats data base structures, transportability of software .user networks must be multidisciplinary					
BRAZIL	.National Institute for Space Research (INPE) .geopolitical and economic mission .wants alternative data source now that Landsat is in private bands .$300M on space between 1981-1995	.GOES and NOAA receiving stations .agrometeorology important to Brazil	.forestry is major application .also agriculture and mineral resources	.oceanography and fishery		

TABLE 2: REMOTE SENSING PROJECTS AND TECHNOLOGY INITIATIVES (cont'd)

COUNTRY	GENERAL	ATMOSPHERE: METEOROLOGY & CHEMISTRY	LAND	OCEANS	SURVEILLANCE	
					NON-MILITARY	MILITARY
ESA		.METEOSAT .2nd generation Meteorological satellite 1994-95 .research tools for meteorologists	.ERS-1 & 2 .all-weather microwave for land R-S .laser ranging .advanced Land-1 & 2 .operational polar orbitters mid-1990's			
Japan	.gradually improve technology to assure constant practical applications (reliability)	.Meterological satellite series .improve vertical sounding	.JERS-1, active & passive R-S	.MOS-1, active & passive		
USA	.more IR .better spectral resolution in all bands: closer to spectroscopic .principle-component method of analysis .onboard reduction of hundreds of channels .interactive systems & expert systems (AI) (cont'd)	.NOAA's - civilian .DMSP's - military	.LANDSAT's .direct mineral identification with microwave & adequate spectral coverage .stress in natural & agricultural vegetation	.TOPEX, surface height to 1-2cms .DMSP .N-ROSS		.'BIG BIRD' & others

TABLE 2: REMOTE SENSING PROJECTS AND TECHNOLOGY INITIATIVES (cont'd)

UNTRY	GENERAL	ATMOSPHERE: METEOROLOGY & CHEMISTRY	LAND	OCEANS	SURVEILLANCE	
					NON-MILITARY	MILITARY
USA ont'd)	.interactive earth processes: CO_2/ SO_2/energy/ hydrologic & other biochemical cycles, complex interraction of land, atmosphere & ocean					
BRAZIL	.will launch 4 of its own satellites for 1989-93 by Brazil's 2-stage solid propellant satellite launch vehicle (VLSS) - 500 kg to 730 km orbit, from Alcantra	.2 meteorology satellites - DCP relays	.built $12M Landsat ground station in 1973 near Cuiaba, updated to receive Landsat 4&5 TM data, now being updated to receive SPOT data .2nd largest consumer of Landsat images (1500 customers) . 2-remote sensing for land and ocean applications			

TABLE 3

A1(b): Trends in Remote Sensing and Likely Status by by 2000 A.D.

- Reduced emphasis on R&D as a proportion of the overall activity.

- Emergence of remote sensing in the marketplace as an information technology available to thousands of users.

- Privatization and commercialization of end-to-end information systems.

- Recognition of the true value to a user of unique information.

- Significant cost increases to reflect the cost-effectiveness.

- Complex multidisciplinary remote sensing systems in space, performing for users on command, for a fee.

- Reliable comparability of different information sources at different times due to the use of accurate radiometric spectral and spatial standards and processing algorithms.

- 'Smart' information systems for non-expert users containing global data interpreted by expert systems (AI), delivering user-specified products, including user-specified synthesis of differently-sensed features.

- Improved management of resource-based economics on the global or national scale through superior forecast models of global parameters.

- Capability, if used, to manipulate and dominate the economies of underdeveloped countries unable to make use of a large global data base. Monopolistic privatization would exacerbate this scenario.

- Breakthroughs in identification and timely use of information features such as mineral deposits, vegetation stress, changes in atmoshperic chemistry.

TABLE 4

Al(c): Key New Technologies in Remote Sensing

- Software for expert systems to select, analyse and interpret, on demand, data in huge data bases.
- Computing hardware with huge matrix processing power and memory capacity for terrestrial use.
- Computing hardware and software for expert systems on manned space stations and unmanned space platforms.
- Onboard preliminary processing and reduction of data from hundreds of spectral channels.
- New data collection systems on satellites with new downlink access to users.
- High-resolution sensors, 'tunable' over wide spectral ranges, on command from disciplinary users.
- Active and passive sensors for atmospheric chemical species in all bands of the electromagnetic spectrum, except the x-ray bands.
- Extensive use of active laser-based sensors.
- Multi-frequency multipolarization radars with controllable pointing and beamshape.
- Polar-orbitting remote-sensing space station with robotic manipulators, precision pointing, huge power demands (for active sensors especially).
- Standards for subsystem interfaces, compatible formats, database structures.
- Transportable software.

REFERENCES

The following reference material has been used in the preparation of this chapter:

1. Interview report with L. Godby, Director General, CCRS, by J.N. Barry

2. Notes prepared by R.M. Freedman from interviews and literature surveys

3. W.D. Carter, A.B. Park New Opportunities for the Private Sector in Space Technology, PECORA VIII Symposium on Satellite Land Remote Sensing Advancements for the Eighties, Sioux Falls, South Dakota, October 4-7, 1983. GLOBEX, Inc.

4. From the Proceedings of the Seventeenth International Symposium on Remote Sensing of Environment, Ann Arbor, Michigan, May 9-13, 1983:

   4.1 Colonel Gilbert D. Rye, U.S. National Space Policy

   4.2 Burton, I. Edelson, NASA's Activities in Remote Sensing

   4.3 Dr. Radford Byerly Jr. A Congressional View of National Policy Directions in Remote Sensing

   4.4 Donn C. Walket, Remote Sensing Commercialization: Views of the Investment Community

   4.5 Pitt G. Thorne, Earth Remote Sensing 1970-1995

   4.6 P.A. Bracker, E.B. Connell, Future Interactive Data Systems

   4.7 D. Wayne Mooneyhan, The Potential of Expert Systems for Remote Sensing

   4.8 Douglas R. Broome, Jr. Future Remote Sensing Instruments and Systems

5. New Scientist, July 25, 1985, p.51

GLOSSARY OF ACRONYMS

DMSP	- Defence Meteorological Satellite Program - U.S. Department of Defense (USAF) - Current, Operational System
ERS-1	- ESA Remote Sensing Satellite-1 - ESA - 1989
JERS-1	- Japan Earth Resources Satellite-1 - Japan - 1989-90
MOMS	- Modular Optoelectronic Multispectral Scanner - FRG
MOS-1	- Marine Observation Satellite-1 - Japan - 1986
NOAA	- National Oceanic and Atmospheric Administration - U.S. Department of Commerce
N-ROSS	- Navy - Remote Oceans Satellite System - U.S. Navy - 1989
SPOT	- Système Probataire d'Obervation de la Terre - France - (late) 1985

APPENDIX 3

TRENDS-SPACE SCIENCE

APPENDIX 3

TRENDS - SPACE SCIENCE

1. POLICIES

1.0 General

1.1 USA

The focus for future space science activities is Space Station. While competing launch facilities will continue to operate, investigations in materials processing and life sciences will take place in manned/unmanned platforms and modules associated with Space Station. Present policies continue the pursuit of knowledge with international cooperation a key attribute. Universities and industry will be involved, with emphasis on ensuring that applications and technology flow from science. US leadership in science will be maintained.

1.2 ESA

Policies are generally similar to those of USA. Europe will consolidate its position in the forefront of science, will aim to link science with industrial development, be a major participant in international space science and contribute to fundamental research. ESA has set a target to increase expenditures annually by 7% starting in 1985, and over the decade 85-95 to maintain science at 15% of overall space expenditures. No Western European country has a completely independent space capability, and each member country's space program is a combination of ESA activities, country programs and bilateral/multilateral cooperative programs.

1.3 Japan

Systematic and effective investments in reseach and facilities are projected, reviewed to maintain capabilities at international levels and to contribute to basic knowledge. There is an emphasis on science activities that have special relevance to Japanese circumstances.

1.4 Germany

Fundamental reseach will be promoted to contribute to cultural development and to guarantee long-term economic efficiency. Projects will be selected based in part on national support capabilities. Emphasis will be on materials science, processing techniques and bio-medicine. Man-in-space will continue to be an important element of the program, which is now well positioned to provide a sound industrial base in space oriented technologies. No independent launch capability appears likely.

1.5 France

The French program is devoted to research in the fields of astronomy and astrophysics, meterology, the structure and environment of the Earth, the solar system, space medicine and physiology and the physics of materials. Many of these are cooperative and include contributions to VEGA (Venus - Hailey's Comet) with the USSR and to Giotto. Analysis of data from space craft such as Voyager has also been part of the program. This form of collaborative understanding will likely continue for the forseeable future. Materials processing has been a very small component of the program.

1.6 Sweden

Sweden has an integrated program involving balloons, rockets and at least one scientific satellite, Viking, scheduled to be launched in 1985. Because of its geographical location, much of Sweden's space science activities focus on phenomena associated with high latitudes, although there are experiments to study stellar and solar radiations.

1.7 Italy

In the past Italy's space science activities have been collaborative with ESA and NASA, but there are signs that national programs will be developed within a decade. Work to date has been in X- and gamma-ray studies, cosmic fireballs, plasma phenomena, ionosphere and IR and sub-millimeter astronomy. Italy was a major contributor to the hardware of Spacelab, and will become more involved in materials processing in the future.

1.8 Australia

Australia will concentrate in the near term in improving its position internationally by undertaking cooperative projects with NASA and UK. While a decision in respect of the specific areas of space science that will be pursued has not been taken, the CSIRO Space Science and Technology Study Group, Working Group on Space Science and Technology Development has identified several opportunities. In atmospheric science, lidar and microwave radar atmospheric sensing techniques will be important. Solar seismology, space-borne VLBI, STARLAB and COLUMBUS present scientific collaborative opportunities. Plasma physics and participation in the International Solar-Terrestrial Physics (ISTP) program are additional possibilities.

1.9 UK

One half space science expenditures go to ESA. Main field of interest has been astronomy, but this may change with the establishment of the British National Space Centre in 1985.

1.10 India

India has developed its own independent launch capability, although it still uses NASA and USSR for these services. The main effort is devoted toward the applications of space, but there is scientific interest in investigations of the terrestrial environment and astronomy. The first scientific satellite was launched in 1975 and carried three experiments - X-ray astonomy, solar physics and aeronomy. It is expected that by the end of the century India will have a very advanced capability in all phases of space research, including materials processing.

II. PROGRAMS

2.0 Atmospheric

2.1 USA

Program objective is to increase the understanding of atmospheric processes, with the operational goal of achieving reliable seven day forecasts. Current projects focus on wind velocity measurements, development of radiometers and Earth radiation budget experiments. In the short term the Shuttle will carry instruments, with an upper atmosphere research satellite planned for late 80's or early 90's.

The primary objective of the satellite program is to obtain an understanding of the mechanisms that control the structure and variability of the upper atmosphere, its response to perturbations and its role in climate. British and French investigators will provide two instruments; the remainder are under developerment in USA. Measurements will include

- trace molecule species
- temperature
- winds
- radiative energy transfer to upper atmosphere

There will be an interactive central data facility with on-line access for use by investigators.

In the decade of the 90's, long-term trends and changes will be investigated. Models will be developed. Measurements will be made from space, sub-orbital observations, land- and sea-based instruments. A polar platform will be required.

In addition to measurements associated specifically with atmospheric phenomona, investigations will be undertaken involving the following:

- circulation, heat content and productivity of oceans

- laser ranging/microwave interferometry for geodynamic measurements
- space plasma physics
- behaviour with time of solar constant, solar spectrum and upper atmosphere
- relate biological variability to physcial characteristics of global oceans
- tethered satellites system (with Italy) for magnetosphere measurements
- topogrpahic experiment for ocean circulation
- scalar and vector magnitudes of Earth's magnetic field
- geopotential research mission
- quantitative study of complete solar-geospace system

2.2 ESA

The current scenario is based upon conventional use of free-flyers placed in orbit by expendable Ariane launchers. If ESA participation in space station involves a man-tended near-polar sun-synchronous platform, a different scenario will be developed. Key decision date is 1986.

The program involves experiments that will have application to:

- radiation balance of Earth
- atmospheric composition and pollution
- atmospheric transport
- environmental monitoring

It is expected that international programs in late 90's will require dedicated monitoring satellites. In the interval, instrument packages wil be integrated into appropriate host satellites.

Passenger payload expenditures will reach 16MAU by 1990 and continue at that level to 1995.

2.3 Japan

To AD 2000, Japan will continue the development of a meteorological satellite series, aiming at achieving a large lifetime for satellite systems.

The vertical structure of the atmosphere will be studied, with development of improved accuracy of observation and more efficient meteorological observation technology.

2.4 Germany

The German program has concentrated on studies of conditions and processes in the upper and middle atmosphere. Two satellites have been operating and data evaluation has been taking place involving a USA and a Japanese satellite. Sounding rockets have also been used.

Studies of the magnetosphere and plasma physics have also been part of the program.

Trace gas measurements and determination of radiation balance have been undertaken. Instrumentation for these measurements has been developed (lasers, radiometers).

2.5 France

France intends to maintain a strong position in Earth Resource studies, of which meteorological investigations form a part. The current program makes use of data collected by various existing satellites - Meteorsat, Landsat, Nimbus-7 - but there will be one instrument in the US Topex that will provide ocean altimetry information.

2.6 Sweden

The main program has been connected with the measurement of air and water pollution. This will continue.

2.7 Italy

Italy provided a radio altimeter for ERS-1, but its future in this type of activity is uncertain.

2.8 Australia

Possible programs in meteorology would involve

- passive sensing of surface pressure
- monitoring cloud height
- lidar wind-finding and constituent monitoring
- monitoring of rainfall over land and oceans
- monitoring emissivity at 10 micrometers

GPS is considered very important for precise positioning, and the development of differentia (VLBI) techniques to overcome need for access to encrypted codes is considered necessary.

2.9 UK

No identified programs

2.10 India

Through the INSAT series of satellites, India has developed sensors and a capability in meteorological investigations. Sensors include a high resolution radiometer and a visible plus IR imager. This series will continue into the 90's.

3.0 Life Sciences

3.1 USA

Immediate programs aim to determine the effects of microgravity on humans operating in space and ways of overcoming the observed problems (acute physiological and psychological phenomena). Measurements of radiation environment and tests of the effects of high energy particles are being made. Human peformance is being investigated.

The origin, evolution and distribution of life and life-related molecules as part of the evolution of the cosmos are being studied. Special instrumentation will be developed to measure the signatures of life-related chemicals both within and outside the solar system.

There is also a program to investigate how gravity affects life on Earth. Work to date suggests that certain biological systems and processes are sensitive to gravity. Near-term studies will seek to identify gravity sensors of plant and animal cells. Long duration experiments will be undertaken on Space Station. Dedicated Spacelab missions are planned for approximately every two years.

During the latter part of the 80's, investigations will continue the studies outlined above. In addition, a space molecule for work with plants, animals lasting months more more will be provided. The search for extraterrestrial intelligence will continue with the development of sophisticated signal processing equipment.

In the 90's extensions of present investigations will take place, with experiments on variable gravity, long term exposure to low gravity and use of data relay satellites to combine measurements from space and Earth.

3.2 ESA

Life sciences activities are presented as part of the EAST microgravity program. They will take place in conjunction with manned facilities (Spacelab) with expenditures included in the overall Spacelab projection of about 250MAU to 1992.

3.3 Japan

Present plans call for utilization of the Shuttle to determine the practical applications that might result from experiments such as separation of bio-materials in space. If any field becomes economic, an applications program will be instituted.

3.4 Germany

The effects of cosmic radiation and weightlessness on humans and lower biological organisms is being studied. Experiments have been carried out in Spacelab and will be followed by other investigations in future similar facilities.

3.5 France

France has carried out several investigations on the behaviour of humans in microgravity as a result of their astronaut's presence aboard the Salyut-7 space station in 1983. There have also been experiments on the efficacy of antibiotics and on the structure of staphylococci cell walls using both balloons and space craft.

3.6 Sweden

No identified program

3.7 Italy

No identified program

3.8 Australia

No identified program

3.9 UK

No identified program

3.10 India

No identified program.

4.0 MICROGRAVITY

4.1 USA

The program focusses on

- crystal growth, solidification, containerless processing
- fluid mechanics, transport phenomena, combustion, cloud physics, critical phenomena
- biotechnology including separation processes, suspension culturing, blood rheology

Four institutional initiatives will be promoted:

- establishment of an advisory group to provide external perspective
- establishment of working group structured on disciplinary lines
- establishment of centres of excellence at universities
- use of Technical Exchange Agreements and JEA's

Eight materials processing systems are now available for rockets and aircraft, with the plan for availability in the Shuttle, Spacelab and free flyers by the late 80's. Twenty-two materials processing instuments are either ready now or will be available by the late 80's. Some 100 experiments have been run already.
Commercialization has been acheived for a limited number

of products, with prospects good for additional products in the near future. Ternary semiconductor fabrication, growth of latex spheres and electrophoretic separations are proven. Commercial interest in this aspect of space R&D is advanced.

4.2 ESA

The program will have two in-space components: utilization of the unmanned platform Eureka, and the manned Spacelab program. Two Eureka flights are scheduled for 89-92 with new major multiuser facilities (MUF) to be compatible with Columbus. Three new facilities will be:

- vapour crystal growth facility
- plant growth chamber or biotechnology facility
- directional solidification facility.

One full Spacelab mission will be flown in 89-92. In addition to existing Spacelab MUF's, six new facilities will be constructed:

- solution growth facility
- melt growth facility
- animal research facility
- fluid science facility
- electrophoretic faciilty
- metallurgical facility.

Overall funding of the microgravity program will be 368MAU to 1992.

4.3 Japan

This program will start with the use of rockets and the development of specialized experimental equipment. The Shuttle will be used about 1988. Depending upon economic outlook, initial experiments will be followed by applications programs.

4.4 Germany

Microgravity experiments focus on:

- producing materials from immiscible melts
- crystal growth from melts and vapour phase
- containerless processing
- reaction kinetics at critical point
- fluid mechanics
- interfacial effects
- transfer phenomena
- molding and casting
- electrophoresis
- ultra high vacuum applications.

This program has developed from rockets to Spacelab and is projected to the use of free-flying retrievable space platforms.

4.5 France

In relation to its other space acitivites, the effort on materials processing is small. However in Spacelab and with the USSR the following experiments have been performed:

- coprecipitation crystal growth
- orientated solidification of eutectic mixtures
- diffusion/interfacial tensions in non-miscible AI/In systems.

Work in this general area will likely increase in the future.

4.6 Sweden

The Swedish program has been concerned with solidification processes in metals and diffusion processes in liquid metals using sounding rockets. When Eureca becomes available, the program will probably increase.

4.7 Italy

Largely theoretical at present, but will grow when Eureca program becomes available.

4.8 Australia

No identified program.

4.9 U.K.

No identified program

4.10 India

No identified program.

5.0 SOLAR SYSTEM

5.1 USA

To date, more than two dozen planets and satellites have been explored at close range and the interplanetary medium has been partially characterized. The sequence for future investigations will be:

- reconnaissance, using a flyby spacecraft
- exploration, entry probes and landers
- intensive study, addressing specific questions.

The recommended approach involves moving forward on a broad front, building on previous technology to accomplish new advances. The move will be toward investigation of specific planets as reconnaissance nears completion. Focus will be on inner planets - Venus, Earth, Mars. The Moon and Mercury will be investigated later. Small bodies will also be studied due to their primitive character. Outer planets are to be explored in the late 80's. Uranus, Pluto and Neptune, being further out, require lon transit times and will be investigated later.

A number of probes have been successfully flown laying the foundation for more detailed investigations. An international Solar Polar Mission is planned for the late 80's, involving cooperation with ESA. The solar system exploration program operates under the guidance of the Solar System Exploration Committee which was established in 1980. The core program recommended by this committee is to focus on missions to inner planets, small bodies and outer planets. They should be designed to use:

- spacecraft inheritance, based on spares from previous projects
- spacecraft derived from production Earth orbiting systems
- new modular design spacecraft.

The USA will focus on what it does best - flyby spacecraft, probes and use of sensor technology. Off-the-shelf hardware will be used wherever possible, and collection of soil samples from, for example Mars, will not be a high priority. At present there is a limit of $300M on the program to the year 2000.

5.2 ESA

The program falls into two parts:

- solar terrestrial program (STP)
- planetary exploration.

The basic elements of the STP will be:

a) a free flyer in Earth orbit with ultra high spatial resolution imaging, and spectrometry in many wavebands simultaneously

b) a Lagrangian point L1 observatory addressing
   - helioseismology
   - solar wind
   - coronol diagnostics

c) synoptic array program covering
   - global magnetic field modelling
   - solar structures and near-Earth events
   - stereo view of coronal structures
   - direction of particles and flares

d) heliosynchronous out-of-ecliptic mission addressing:
   - evolution of solar structures/solar wind
   - frequent coverage
   - stereoscopic viewing

e) solar probe
   - in situ measurements of corona
   - solar gravity field
   - testing of General Relativity

f) space plasma physics.

In the field of planetary sciences, the following elements are planned:

- Mars orbiter
- lunar orbiter
- comet flyby
- multiple Venus orbiters.

More advanced missions will include:

- Mercury orbiter
- Saturn orbiter/Titan probe
- comet sample return
- Mars rover mission.

Some of the above will be joint with USA.

5.3 Japan

Scientific exploration of the Moon and Earth-type planets will take place. Provision has been made for investigation of Jupiter-type planets, depending upon technological progress and international circumstances.

5.4 Germany

Because of extremely heavy cost of planetary research projects using space craft, Germany will provide individual experiments for integration into bilateral programs. Germany will contribute the Galileo project by providing the Energetic Particles Investigation payload, as well as a Helium abundance instrument and dust collectors. Instrumentation will also be provided for Giotto. Eureca is being considered for the German Infrared Laboratory in the early 90's.

5.5 France

France is making major contributions to two programs, VEGA and Giotto. The former involves a Venus probe with a lander and balloon, and a Halley's comet probe, and the latter an encounter probe for Halley's comet. There is an on-going program dealing with analysis of data from probes such as Voyager and Viking. From the latter, the gravitational field of Mars has been determined. The abundance of Helium and Hydrogen in Jupiter has also been determined. These types of investigation will continue.

5.6 Sweden

Activities are mainly involved with studies of solar UV and IR, using satellites, balloons and rockets. There is involvement in Giotto.

5.7 Italy

Present work deals with space plasma phenomena and the magnetosphere.

5.8 Australia

Preliminary joint R&D with the US is underway in order to propose a joint solar seismology experiment.

There are a number of possibilities in plasma physics:

- naturally occurring irregularities in the ionosphere
- artificial stimulation of instabilities in the ionosphere
- artificially stimulated instabilities in space plasma
- high latitude magnetospheric physics

Australia could participate in ISTP through the Scientific Committee for Solar Terrestrial Physics, which is responsible for developing the program, and of which Australia is a member. May take over some satellites originally proposed by USA.

5.9 UK

No identified program.

5.10 India

Some interest, but no identified program.

6.0 Distant Universe

6.1 USA

The strategy for study is based upon

- detect gross features
- initial all-sky surveys
- high sensitivity surveys
- use of full-scale observations
- specialized follow-up

The Hubble 2.4m space telescope is planned for launch in the near future and will be a long duration facility serviced by the Shuttle. It will be used to determine the rotation, age, mass and chemical composition of the stars. A number of specialized observatories will also be used to study the full spectrum of em radiation. Some of these will be shared with Germany, UK and France.

Plans for the 90's include an advanced solar observatory which will have a soft x-ray facility, a pin-hole occulter to observe the corona close to the sun's surface, a high-resolution gamma ray spectrometer and a low-frequency radio facility. Special techniques for study of infra-red and deep space x-ray are to be developed, and one element of a VLBI is projected.

6.2 ESA

Two main concepts are scheduled to be cornerstones of this program

- high energy astrophysics
- UV, optical astronomy

Three other astronomical concepts will also be pursued

- infrared
- sub-millimeter
- radio (VLBI)

Funding is projected to go from 143MAU in 1985 to 204MAU in 1991.

6.3 Japan

Small/medium-sized observation satellites will be launched at the rate of one per year, with larger sized every few years.

6.4 Germany

Areas in this program will include

- gamma ray investigations
- IR investigations
- UV investigations
- optical region investigations
- x-ray investigations
- stellar astronomy

6.5 France

Past program elements have included

- study of gamm bursts
- mapping of low energy gamma sources
- X- and gamma-ray astronomy package
- preparation of focal-plane instruments for ISO program

6.6 Sweden

The main emphasis is on UV and IR studies.

6.7 Italy

Work to date has been almost entirely in conjnction with ESA and NASA and has covered investigation of cosmic sources of X- and gamma-rays and cosmic fireballs.

6.8 Australia

Participation with other countries in order to get up on the learning curve and to contribute key technology. STARLAB and COLUMBUS have been identified for possible collaboration.

6.9 UK

The main field of space science pursued is astronomy, funded by SERC. In 1983/84, SERC provided 22M pounds, about half of which went to ESA.

6.10 India

The first Indian scientific satellite launched in 1975 carried one experiment on X-ray astronomy. The satellite failed after five days. There is no identified program at this time, although there are developments in the satellite field that could lead to further astronomical studies in the future.

III. THE AD2000 EXPERIMENT

3.0 General

Space science plans extending to the end of the century are at very different stages in different countries. In the Western World (Canada is excluded), the leaders are USA and ESA, with Japan, Germany, France, Italy and possibly Sweden in a second tier. Present forecasts are generally based on a steady progression from the present, with efforts on the part of the third tier countries to "leap frog" into at least the second tier.

The significant unknown is the USSR. Compared to the USA, where roughly 100 materials processing experiments have been flown, the USSR has conducted some 1500. Some materials so produced have been placed in service (commercialized in Western parlance). The USSR space infrastructure, while not yet including a shuttle, is expected to do so by the end of the decade - one with considerably increased payload capacity over STS. They also have a booster capable of putting about 300,000 lbs into orbit. Their infrastructure, assuming all technologies work, will allow them to establish a Moon-base in the early 90's. This could cause a post-Sputnik type scramble - particularly in the USA - which would radically alter priorities and would impact on the direction for space science in the late 90's.

While any major USSR achievement will need to be assessed in terms of the impact on the AD2000 environment, there is no indication in any of the present country plans that significant cooperation in major USSR progrrams is contemplated. The assessment that follows is based upon information currently available on country programs to AD2000.

3.1 Atmosphere

With the projected effort in measurement over the next 15 years, models of the behaviour of the atmosphere should be at first generation stage. Weather prediction will have improved, not just through phenomenological observations, but by virtue of a much better understanding of the basic processors at work. The science directions will likely be dependent on the technological advances in instrumentation and the design of measuring devices to be constructed in space. These will take a very different form from those in use in a gravity environment.

Data will be collected at rates that will need new technology in order to assimilate and apply them to model refinement. Although weather forecasting will still be a major objective, other atmospheric studies relating to "pollution" will achieve prominence. In particular, the dynamic relationship between solar energy, global biological phenomena and the atmosphere will be the subject of detailed study.

The magnetosphere will be better understood, but opportunities for scientific investigation in this area, as well as plasma physics will be present.

Since much of the science associated with the "atmospheric" phenomena is a public good, - and very expensive - the trend will continue toward international cooperative ventures. The number of countries wishing to participate will increase significantly, and this will impact on the number of opportunities. The very recent trend has been to devote resources to the applied areas of space investigation. If this continues - and with long lead times this well could - only the very significant projects will be funded, and only the top principal investigators will be able to participate.

3.2 Life Sciences

Assuming that the results of the USSR investigations become available, the ability to live and work in microgravity over extended periods will have been achieved. Space life science will focus on the examination of the effects of microgravity on a variety of biological "colonies" over long periods. There will also be "pre-visitation" research on the possible effects of placing biological species on hitherto barren planets/asteroids.

Emphasis on space life sciences is unlikely to extend beyond those countries who have already established programs in this area. We there expect that the USA and ESA will be the main perfomers, with key specialists from other countries contributing to the "national" programs. Assuming that ESA achieves its goal to become independent of USA, there will be two camps in the Western World.

3.3 Microgravity

Materials prőcessing in microgravity has attracted the most attention because of potential commercial opportunities. During the next 15 years, these activities will increase; opportunities for investigation will be enchanced by the availability of a large number of platforms - tended, untended and manned. Materials processing has been a significant field for scientific research over the years, and there is every indication that this will extend into microgravity.

The barrier that many countries will face is their inability to get onto a very expensive learning curve. At present, opportunities are scarce - at least relative to the number of proposals; only the best can be accommodated, so that unless there is a will to make investments (Germany in Spacelab for instance), the way ahead will be difficult.

By AD 2000, the commercial forecasts will have been validated, and microgravity will present a picture similar to materials processing on Earth. Industries will have production facilities with associated R & D. There will be a science component - as there is now - operating at about 10% of overall R & D expenditures. Leaders will be USA, ESA (largely generic) Germany, Japan, with France and Italy possibilities. Investments bweing made now will ensure their pre-eminence by the turn of the century.

Selection of science proposals will continue to favour the proven investigators, which implies that the present performers will continue to be the leaders. Each country will try to focus on areas appropriate to industrial interests and the competition will dictate who will dominate what fields. Any country that intends to maintain competitive manufactuing industries will need to devote some resources to investgiations in microgravity.

3.4 Solar System

There is much evidence from current country plans that studies on our solar system will be enriched and extended. The ability to launch satelllited/probes on a regular basis; repair and overhaul facilities of space station; vastly improved computational power; all these provide the infrastructure to examine in detail and at close poximity a very fruitful domain of science. There is no evidence that this field will be mined out in the forseeable future; it will be costly howeve,r and joint endeavours will be the dominant method of investigation.

The USA will observe and touch; ESA will go further, to the collection and return of samples from planets/asteroids. As noted above, USSR initiatives may well cause a change in plans. Should sample retrievel become part of international programs, geologists will have an opportunity to rejoin the space science community.

In any event, there will be many opportunities for physicists to pursue their vocation in areas relating to solar system studies.

3.5 Distant Universe

Space station will be a key element of programs to probe the distant universe. Very large telescopes can be constructed, refurbished and repaired in space, giving virtually unrestricted opportunities to construct laboratories for observing and recording emissions from outside our solar system.

Space will provide the next frontier from which astronomers and physicists can examine the universe. Opportunities will be immense; joint activities a necessity. Countries will wish to participate when there is demonstrated competence within the home community to contribute. Furthermore, no competence, no invitation to join. As with other areas in space science, ability to work in the field in the 21st century will depend upon the resolve to lay the foundations now.

APPENDIX 4

THE IMPACT AND USE OF THE REGULATORY MECHANISM IN THE DEVELOPMENT OF NATIONAL AND INTERNATIONAL SPACE STRATEGIES

Regulations pertaining to space communications developed naturally as an extension of already existing radio regulations. The body of the ITU responsible for setting such regulations is the Comité Consultif Internationale Radio (CCIR). With no significant exceptions, all nations are members of the CCIR. Membership is limited to government authorities except by invitation of the government concerned. The various sub-committees of CCIR draft "Resolutions" which are approved by the signatories and then have the force of international agreements.

Typical outputs of CCIR are frequency allocations on an international basis for satellite communications, the definition of technical parameters for satellite transmissions, the agreement on spacing of satellites in the geosynchronous orbit, and the allocation of orbital positions to individual nations.

Within the general bounds of the CCIR resolutions, individual countries have the right to allocate frequencies for specific purposes or to specific entities, and to make other decisions or regulations on a national basis pertaining to the matters carried by a specific CCIR resolution, providing that such resolutions or decisions do not conflict with the requirements of the resolutions.

In addition to the regulatory type of control imposed on nations by CCIR a number of major international agreements are in force that place limits on the use of satellite communications by their signatories. The major agreements under these headings are the:

- Intelsat agreement
- Inmarsat agreement

Intelsat is an international joint venture organization providing space communications services via a large number of advanced communications satellites in geosynchronus orbit (see also Appendix A). There are currently over a hundred signatories to the Intelsat Agreement including the Peoples' Republic of China but not the USSR. Signatories undertake, amongst other things, to not operate their own national satellites in competition with Intelsat, and to carry out frequency coordination with Intelsat for their own domestic satellites. Canada is a signatory to the Intelsat agreement.

Inmarsat is the acronym for the International Inmarsat organization. Inmarsat provides communications via satellite to the shipping offshore industries around the world. Current membership is slightly over 40 nations with the largest participation being that of the United States with the Soviet Union being second. Canada is also a signatory to the Inmarsat agreement which provides for similar, but not identical, cooperation on the part of its members to that of the Intelsat Agreement.

In addition to being a signatory of these two major space communication agreements, Canada has a bilateral agreement with the United States regarding reception and use of each other's domestic space communications satellites. While it is not the purpose of this Chapter to detail the clauses of various agreements, the U.S./Canada bilateral agreement on Space Communications has as its prime clauses the restriction of the use of the other country's satellites to secondary, rather than prime applications, and the coordination of all activities pertaining to the other country's satellites through a designated entity. This designated entity in the case of Canada, is Telesat Canada.

Thus, any consideration of Canadian Strategic Space Communications Policies and the implementation of the various policies through the regulatory tool must take into account the various international and bilateral agreements to which Canada is a signatory.

The situation regarding the international regulation of space science activities is somewhat different. There is no international organization similar to CCIR relating to space science, nor is there an apparant need for one. There is however, a need for agreement and cooperation on an international basis for many, if not all, space science activities.

The needs of such international cooperation and coordination is normally fulfilled by specific agreements or Memoranda of Understanding (MOU) between the nations concerned in, or affected by, a given space science program. Thus, most space science international agreements are program specific, and are enforced only for the duration of the program. For example, in 1979 there were 48 such agreements in operation between Canada and the United States alone. Due to the program specific nature of such agreements, the actual number and their impact on future plans must be reviewed for any particular time frame of interest.

These agreements take different forms, but in the case of U.S./Canadian space science memoranda of understanding a common basic premise is that the MOU shall define in detail what each partner shall contribute to the program with the objective minimizing or eliminating actual cash flow between the two countries. In contrast to this space science agreements between members of the European Space Agency, including Canada as a contributing member, are usually based upon proportional monetary contributions and the allocation of contracts to participating member nations based upon the proportions of their monetary contribution.

It should perhaps be mentioned that the current ad hoc mechanisms for international agreement, cooperation and funding of space science activities appear on the whole to be satisfactory and to meet the needs of the space science community and the national governments sponsoring this community.

The final segment of space commercializaion to be addressed in this chapter is that of remote sensing. Here the matter of regulation and international agreement is more complex and is currently ill defined.

The commercialization of remote sensing from space is currently in its initial stages. The major participants are the United States, the USSR, and the European Space Agency. Canada has plans for its own remote sensing satellite, Radarsat, whose prime, but not only, mission is that of ice reconnaisance.

Current remote sensing satellite missions are typified by the United States NOAA weather satellites and the pre-operational Landsat and Nimbus satellites. Most remote sensing satellites operate in low earth orbits to obtain maximum resolution of their images, and often in polar or semi-polar orbits. A prime characteristic of such semi-polar low earth orbits is that virtually whole earth coverage is obtained over a period of a few days. Such universal coverage gives rise to a number of important international policy considerations, including the right of one nation to obtain and use images of other nations without their approval or permission. Currently the United States, and to a lesser extent, the other operators of remote sensing satellites, have prevented a major international confrontation on this matter by making all images obtained by remote sensing satellites freely available.

There are obvious limitations to such a policy both on the part of the nation obtaining the images, and the nations over which the images were taken. Over the next 15 years, as the commercialization of remote sensing expands and matures, that this matter of remote sensing rights will come to the fore and will need to be addressed on an international basis. As a result of Canada's needs and plans in the field of remote sensing from space, equitable solutions to these matters can validly be expected to be of major concern to Canada.

Of equal concern to that of rights of remote sensing from space, is that of standards for remote sensing from space. As mentioned above, the CCIR has for most of this century successfully devised standards for international radio communication, permitting nations to electronically communicate with each other with ease. Currently there are no such standards that the reception and processing of data from the variety of remote sensing satellites in operation. Each satellite operates with its own data formats, protocols and architecture. To date this has not been a major problem as there are a limited number of remote sensing satellites. However, over the period from now till the end of the century, remote sensing satellites are likely to proliferate and the need for international organization to develop acceptable worldwide standards will become of major importance. Once more this is an area which is likely to be of considerable concern to Canada and its future space strategy.

1.3 The Impact of the National Regulatory Environment on the Commercialization of Space.

Over the last 20 years or so of space commercialization, the regulatory policies imposed by individual nations have been shown to have a critical impact upon the development of national space industries. Given hereunder is a brief review of the national regulatory policies on space in:

- U.S.A.
- Japan
- United Kingdom, and
- Canada

together with some conclusions and opinions as to the national impact of these space policies.

In the United States the development of domestic communications systems was a natural extension of the U.S. role in Intelsat and in military space communications. The regulatory authority in the United States for satellite communications is the Federal Communications Commission, (FCC), the organization that has traditionally regulated all communications matters in the U.S. In addition, for certain aspects of communications regulation relating to the field of aeronautics, the Federal Aeronautical Authority (FAA) has some limited jurisdiction.

The FCC did not permit domestic communications satellites in the United States until 1976, some three years after the commencement of Canada's domestic satellite service. In 1976 there was a distinct U.S. government policy trend towards deregulation. Thus, the so-called "open skies" policy was developed. This regulatory policy was a very loose one requiring only that applicants for private sector satellites, transmit and receive earth stations, and for new and innovative services to be carried over the satellite system, show technical and financial ability to fulfill the terms of their application. In addition, applicants for the operation of private satellites and for transmit ground stations were required to meet international standards for technical parameters affecting the use of the satellite and potential interference with other users of the satellite or of the radio spectrum. In cases where there was more than one applicant for a particular orbital slot, the FCC used a vriety of mechanisms to select a licensee.

This minimum regulatory policy coincided with the availability of appropriate technologies derived from the U.S. role in Intelsat and in military space communications, and with new applications for space communications such as Pay TV, Cable Television, video conferencing and a multitude of high speed data business applications. This coincidence of minimum, but possibly appropriate, regulation, a new and rapidly developing technology, and an expanding, innovative and ready market, lead to extremely rapid commercialization of space communications in the U.S. domestic field. A spin-off of this was a domination of the international space communications market which continues today, although to a lessening extent. It could thus be argued that a liberal regulatory policy is appropriate for a sector where the technology and applications are developing hand in hand. The argument is less persuasive for a maturing market and applications, particularly where there is a possibility of negative international impact such as the pro rata availablility of geosynchronous orbital slots.

In remote sensing the U.S. policy dictated essentially zero regulation. Images from U.S. government commercially oriented remote sensing satellites were generally available at minimum or no cost to all countries who had the technology to interpret them. This policy has delayed major international consideration of rights regarding commercial remote sensing and the exploitation of images gained by such remote sensing over foreign territory. There have been a number of questions in various fora including the United Nations, but it has not yet reached the proportions of a confrontation. The current policy of the Reagan administration is to transfer remote sensing to the private sector, and to implement cost recovery for the use of the images obtained. So far this has had only limited success, and as additional remote sensing satellites are launched and become operational, for example the SSM/I, it is reasonable to expect some modification of U.S. national policies, and perhaps some regulation, regarding remote sensing satellites.

As mentioned earlier, space science activities, primarily through NASA, are normally handled by project specific bilateral or multi-lateral agreements where foreign countries are involved.

In Japan the approach to regulation in the satellite communications sector has followed the traditional very close liaison between government and industry. Japan's operational involvement in communication satellites has been a slow and cautious one, based upon many years of experimental work and careful cooperative investigation of the impact of satellite communications on the extensive existing terrestrial network. The current operational satellites makes use of spread spectrum techniques to minimize the impact on the terrestrial networks sharing the same band thus avoiding many of the problems that occurred under the loose regulation in the United States. In addition, use is made of the EHF unshared band for satellite communications to license private network operators to set-up and operate private satellite data networks to, for example, company offices spread throughout to the large number of islands that make up Japan. In summary, long and careful experimentation and close liaison between the public and private sectors has resulted in a regulatory system that encourages the private sector to make use of satellite communications while avoiding many of the problems that can arise with very minimal regulation.

While Japan does not at this time have operational mobile satellites, much experimental work is being carried on and it is valid to expect a similar well thought-out regulatory environment to be imposed upon future operational mobile satellites.

There are many indications that Japan is moving to a position where, from the viewpoint of technology and applications, as well as by careful national and international moves, it will be a serious challenger to the current U.S. supremacy in the commercialization of space. Many sources feel that by the end of the century Japanese domination of space commercialization is likely to be an accepted fact.

It can be arguably stated on the other hand that the United Kingdom has been the victim of over-regulation, coupled with major changes in government policy that have effectively inhibited both the private sector and the public sector from effectively entering the domestic communications satellite field. While the United Kingdom is an active member of Intelsat, Inmarsat and ESA, it has yet to launch its own domestic satellite. Current regulations pertaining to the use of the satellites of other nations for the reception of video signals are restrictive in the extreme (see Appendix A). Early this year (1985) the implementation of a United Kingdom Space Agency was announced. One of the purposes of this agency is to provide a stable environment for the exploitation and commercialization of space by the United Kingdom. This agency can be expected to be active in the international space regulations field in the near future.

In Canada, the regulatory bodies for space communications are the CRTC and the DOC. The DOC has the responsibility for issuing licenses and for policies in relation to the issuance of licenses. The CRTC has a dual responsibility, the implementation of the broadcasting act, and the regulation of the federally incorporated telecommunications common carriers including Telesat Canada.

Under the Telesat Canada Act, Telesat Canada has the full responsibility for Canadian domestic satellite communications systems. From the commencement of service, in 1973 via Anik Al, the Telesat Act was interpreted to mean that Telesat Canada had the monopoly over all segments of the satellite system including both transmit and receive earth stations of all types, as well as the space segment. A number of regulations were promulgated to support this interpretation, and DOC issued transmit, receive, and satellite segment licenses to Telesat Canada accordingly. This was slightly modified to permit authorized common telephone carriers to own their own receive stations, but for many years Telesat Canada was, through legislative act and regulation, granted full monopoly powers over Canada's domestic satellite system.

During the first five years of operation, Telesat Canada received a number of applications for innovative use of the satellite system by Cable TV operators and others, but it can be argued that it used its monopolistic powers to enforce terms and conditions which were commercially unacceptable to these entities. Thus, for the first 8 years or so of its existence, Telesat Canada's customers were limited to the common carriers and the CBC, with other potential users discouraged by high prices and lack of customer control of even the receive ground stations. The regulations that enforced this situation were, in part, the implementation of a policy to protect Canada's broadcast system from an influx of foreign programming and undue competition by the cable television industry.

The last five years has seen a slow but continuing liberalization of Canada's regulations regarding ownership of earth stations, both transmit and receive, and of the constraints put onto Telesat Canada by both its membership of Telecom Canada and the CRTC. This liberalization has over the last three years permitted the use of the Canadian domestic satellite system by Pay TV licensees, a number of TV stations and by Canadian Satellite Communications Inc. (Cancom). In addition, a number of radio broadcasters use the system to broadcast radio network programming and there are a number of other private sector users. In addition Telesat Canada has recently applied to CRTC, and received permission, to modify its tariffs on a temporary basis to supply service to new potential users of the system under its experimental program, in an effort to attract new business to its under-utilized system.

A number of sources feel that the liberalization of Canada's satellite communications regulations has been made too late to attract large numbers of commercial users. Plans by the telephone common carriers for a coast-to-coast fibre optic trunk system to be implemented over the next five years has brought statements from both common carriers and from the CBC that they are likely to withdraw most of their services from communications satellites and instead use the terrestrial fibre optic coast-to-coast network.

The operation of Canada's domestic satellite system has from the beginning been complicated by its joint government/telephone common carrier ownership which has lead to a number of restraints in its operation that arguably can be said to have prevented it from attracting full loading to its technically excellent system. Recent relaxation in regulations permit a freer use of the system, and private ownership of both transmit and receive sites, whilst encouraging some commercial use of the system. It remains to be seen however, whether this regulatory change will be sufficient to turn Telesat Canada, and Canada's domestic space system into a booming profitable entity.

* * *

NOTE TO MANUFACTURERS AND DISTRIBUTORS OF DISH ANTENNAE

The state of the law relating to the use of dish antennae in Great Britain is, at the date of this note, as follows:-

1. **DTI Licence**

A dish user must be licensed by the Department of Trade and Industry. Two forms of licence are available for the reception of signals from point to point communication relay satellites:

(A) A Testing and Development Licence.

(B) A Demonstration Licence, enabling the technology of satellite television reception to be demonstrated in the United Kingdom to trade and public audiences. The conditions attached to this licence take into account the fact that in the United Kingdom general reception of transmissions from satellites operating in bands which are designated for use of communication relay satellite services is not permitted. There are, as yet, no direct broadcast satellites serving the UK.

Licences will in general only be issued to applicants with testing and development objectives.

The general conditions of both types of licence are as follows:

- No protection against harmful interference will be accorded to the reception authorised.

- Reception shall be solely of television visual picture/sound relay transmissions whose originators permit such reception by providing authority in writing for each installation.

- The transmissions received shall not be relayed or distributed to third parties in any form, whether live or recorded, even for test, development or demonstration purposes, except for conditions below.

Also the following condition applies to the Demonstration Licence only:-

- In any trade or public demonstration of the receiving equipment a copy or copies of the following notice shall be conspicuously displayed so as to be easily visible to persons viewing the transmissions received:

  "This demonstration of satellite television reception makes use of signals received from a point-to-point communication relay satellite, not a broadcasting satellite. The Department of Trade and Industry Radio Regulatory Division has advised that reception of such transmissions is authorised only for testing, development and demonstration purposes. Such reception is not covered by the Broadcasting Receiving Licence, and licences are not available for general public reception of these transmissions. There are no satellites yet in operation carrying broadcast programmes intended to be directly receivable by the general public. The first such service intended for broadcasting service from the UNISTAT satellite, is due to come into operation in 1987/8. Reception of satellite television transmissions without a licence from the Department of Trade and Industry is a contravention of the Wireless Telegraphy Act."

In addition, copies of the demonstrators' notes of authority to receive programme providers' signals shall be similarly displayed.

2. **Planning Permission**

A dish user must obtain planning permission for the installation of the dish from his local planning authority.

of new or advanced sensor and data processing technologies.

The end of the century will be characterized by a plurality of remote sensing satellites carrying optical and microwave sensors - some operational, others experimental. Each will be optimized to suit the requirements of its owners. At least two commercial polar orbiting satellites will be operating - EOSat's Landsat and France's Spot. The 20-month delay between the future failure of Landsat-5 (mid-1987) and its successor places Spot in a strong position to capture a large portion of the commercial raw data market in the late 1980s. Those users that rely on such data in an operational mode will be forced to pay the switching costs, and some are not likely to switch back when Landsat 6 comes on stream.

The large number of microwave environmental satellites coming into service in the late 1980s and early 1990s is staggering (six with SAR, four with Microwave radiometers). Fortunately there are differences in orbits, frequencies, special features and total sensor complement that tend to give each satellite a special role. These satellites are intended to be used for operational purposes, so that their replacements should be flying in AD 2000. By that year, most major nation's weather and environmental forecasting services will be employing numerical forecasting and will have integrated satellite numerical data and imagery into routine operations.

Value added services using remote sensing satellite data should be big business by the year 2000. The size and growth of this business will depend somewhat on how readily the gap in Landsat data can be filled with Spot data. Operational users would lose faith if a serious gap in data availability occurred. While government action has inadvertently slowed the introduction of value added services as a business (by essentially providing such services free), more recent governmment actions have been designed to foster such a market.

3.6 Space Science

3.6.1 Introduction

For the purpose of developing an AD 2000 scenario, space science is subdivided into the following areas:

- distant universe
- solar system
- earth and atmosphere
- life sciences

Microgravity and materials processing will be dealt with in Section 3.8.

Observation of the distant universe includes measurement of the radiation and particles reaching earth from beyond the solar system, and study of the sun as the only star that can be observed in detail. Basic objectives of such research is to gain an understanding of the origin, structure and evolution of the universe, and the physical laws that govern it. From space, a view of the universe is unobscured by the earth's atmosphere.

Solar system research involves studying and visiting objects and environments in or near the solar system in order to investigate its origin and evolution. Measurements focus on internal structures, surface features, atmospheres and plasma environments which require remote and in-situ observations and sample returns.

Research on earth and its atmosphere includes remote sensing from orbit, and measurement of the electric and magnetic fields and particles in the vicinity of the earth to determine how the planet, land surfaces, oceans, atmosphere and plasmasphere function and interact. Other important questions addressed in such research are how life originated, has evolved and is maintained.

Life sciences studies seek to ensure the health, safety, well-being and effective performance of humans in space, and to prepare for a major increase in human activity as space station and an in-orbit infrastructure evolve. Such studies also use the space environment to further knowledge in medicine and biology by exposing living organisms to space and observing the effects.

3.6.2 Distant Universe

The principle element in NASA's current astronomy program is the 2.4 m. Hubble space telescope to be launched by the Shuttle in 1986. It will be a long duration facility to be serviced by the Shuttle crew. One of the focal plane instruments and the solar arrays are being provided by ESA. The space telescope's ability to cover a wide range of wavelengths from the IR to the UV, its high resolution and its ability to detect faint sources make it the most powerful astronomical telescope ever built. Other current programs include ultraviolet, x-ray and infrared detection systems, a cosmic ray explorer and a heavy nuclei collector. In addition, the Shuttle-launched Space lab, a joint NASA-European program, will contain telescopes to observe the universe over a wide range of wavelengths , but with emphasis on the ultraviolet which is normally absorbed by the atmosphere.

Future programs of the 1980s include an advanced x-ray astrophysics facility, a gravity probe to test general relativity, an infrared telescope cryogenically cooled, a solar seismology mission, an extreme ultraviolet explorer, an x-ray timing explorer, a solar corona diagnostics mission and further Spacelab experiments.

During the 1990s, Space Station will become available both